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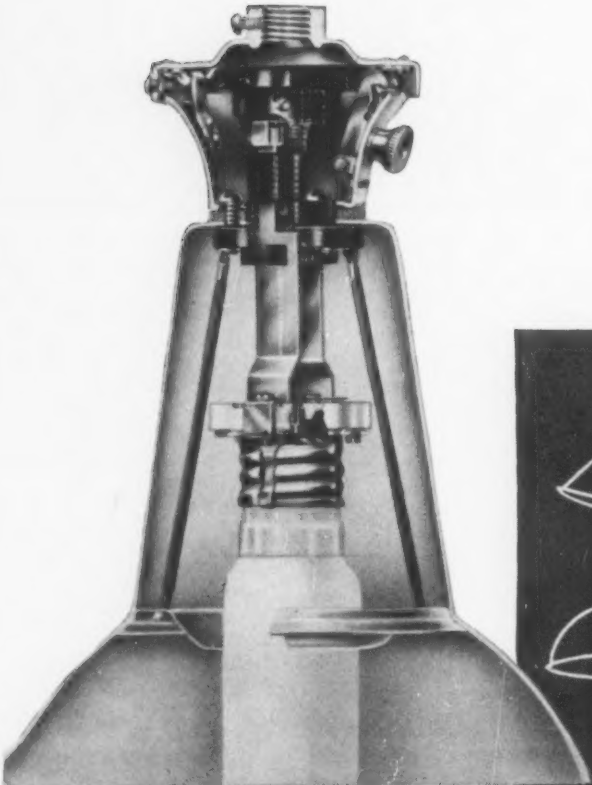

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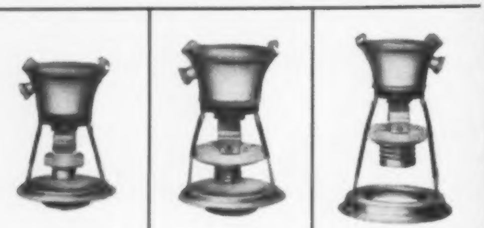

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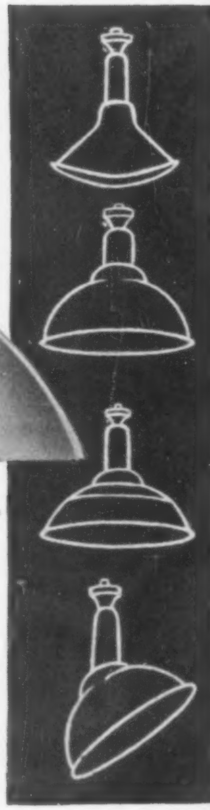

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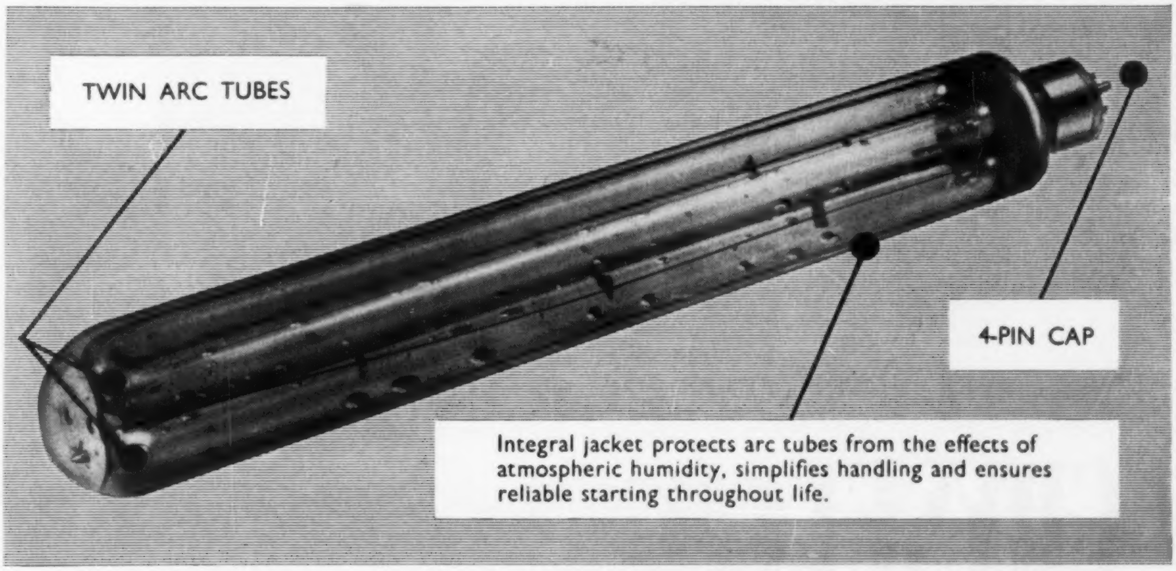

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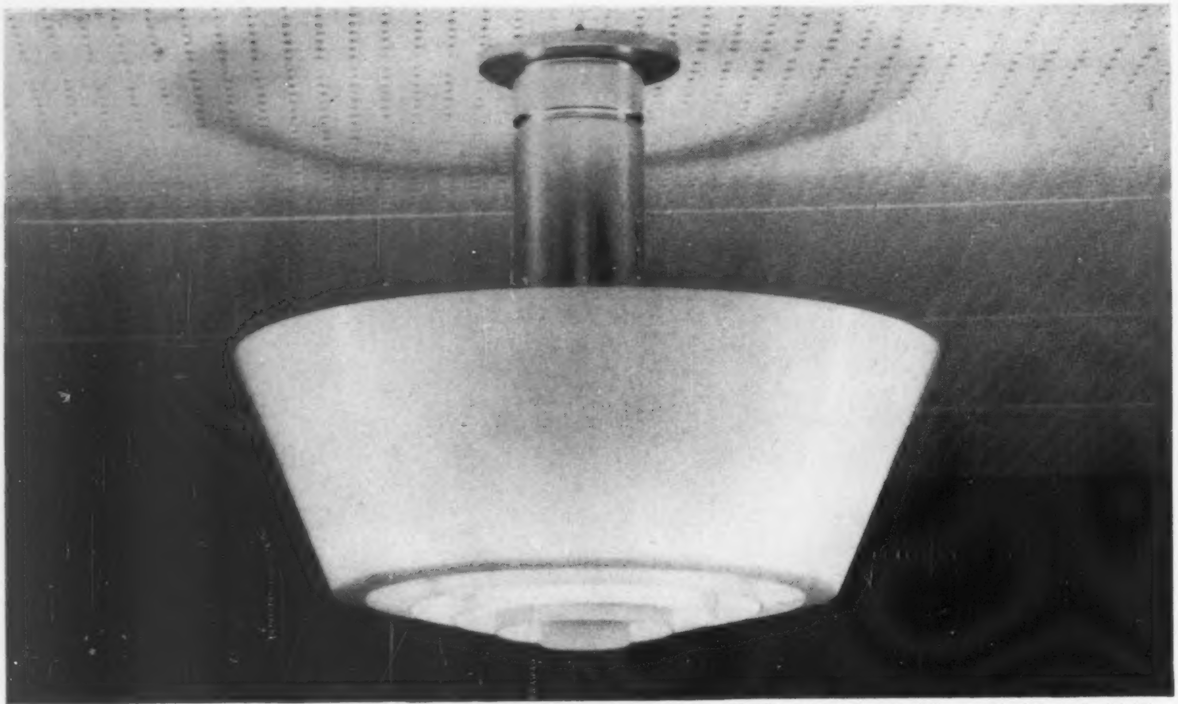

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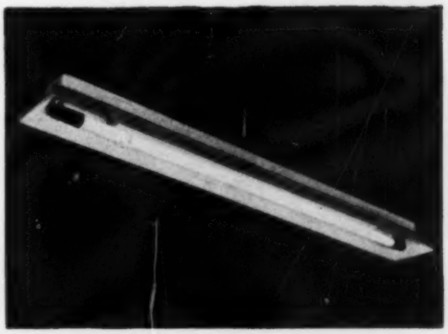

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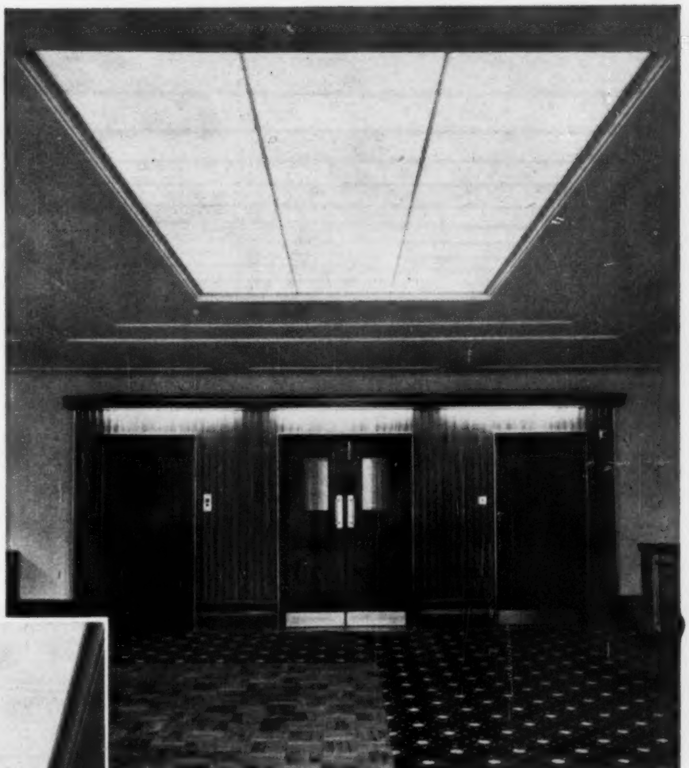

The entrance hall of The Equity and Law Life Assurance Society's new offices at St. Johns, Hazlemere, Bucks. The ceiling lighting has PLASMATIC* diffuser panels extruded in Erinoid light-stabilised polystyrene by Tube Lamination and Engineering Limited. Inset shows the ease with which these panels can be removed for cleaning.

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Light and LIGHTING

Vol. 51. No. 12. December, 1958

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contents

Research and Development

THE results of individual researches are seldom dramatic. More often, numerous pieces of research are done before enough knowledge is acquired for the emergence of some new findings of such importance that it becomes front-page news in the popular press. In our own time, however, there has been a sufficient number of remarkable results of scientific researches in different fields not only to hit the headlines but also to give the general public a wholesome respect and admiration for what it calls "the back-room boys." Whether research is aimed at the solution of such weighty problems as the causation and cure of disease or of such problems as stand in the way of the achievement of better utilities—as light sources, for example—it calls for patient, painstaking, skilful work, for clear, logical thinking and for uncompromising intellectual honesty. From the research laboratories of member companies of the lighting industry many notable results have come and, no doubt, there are more to follow. We hope that those who commercialise these results have an adequate appreciation of what they owe to those who get them.

This 14-ft. diameter fitting in the Oxford Street offices of Cedok—the Czechoslovak travel organisation—consists of two brass rings concealing about fourteen tungsten lamps. The premises, which were designed by Dinerman, Davison and Hillman, and are described on the opposite page, are lit mainly by spilt light from illuminated showcases, screens and canopies.

More than any other industry—except, of course, the footwear industry—the travel industry is keenly aware of the role that architecture, lighting and interior *décor* can play in boosting turnover and fighting competition. The various international airlines, in particular, have achieved a reputation for elaborate and expensive-looking premises which many members of the public criticise as needlessly extravagant. But good design is not necessarily costly, and the lighting schemes of the four central London travel bureaux illustrated in this feature are notable as examples of sensitive handling of simple techniques rather than essays into the realms of flamboyance or opulence.

MAKING LIGHTING PAY

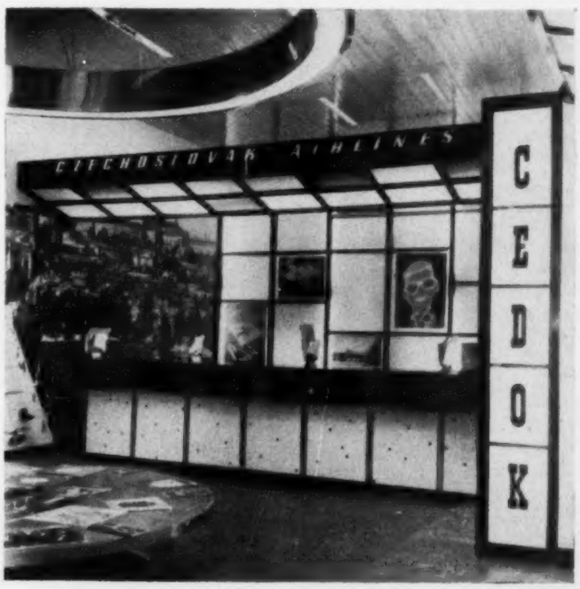
Four Central London Travel Bureaux

1 THE Cedok office is a combined information bureau for the Czechoslovak Travel Organisation and the Czechoslovak Airlines (CSA), as well as a showroom for Jaco Jewelry. The travel counter is at the end of the rather narrow premises in Oxford Street; behind it there is a floor-to-ceiling screen of illuminated plastic panels into which photographs and posters can be fixed. Dominating the bureau, which was designed by Dinerman, Davison & Hillman, is a circular brass lighting fitting, 14 ft. in diameter, housing about 14 tungsten lamps. Beneath this fitting and reflecting its shape is a 10-ft.-diameter mahogany table on brass legs.

Lighting, apart from the fitting described above, is mainly by spilt light from the illuminated display fittings and from the illuminated canopies over the seating area and the travel counter. These canopies are in the form of grids, filled with plastic panels—mostly white, others red or blue, these being the Czechoslovak national colours. Additional lighting comes from rectangular panels in the same three colours and in various shapes recessed into the ceiling of hardwood boarding, and from irregularly shaped recesses in the left-hand wall, the backs of which are of coloured plastic concealing tungsten lamps.

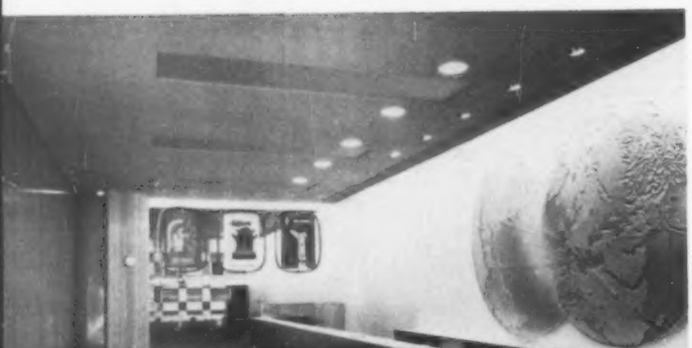
There are two windows: one, devoted to jewellery displays, is lit by about twelve long, thin cylinders, with a matt-black finish, suspended at different levels over the jewellery; the other, the airline's window, is lit by twelve adjustable reflector spotlights recessed into the soffit. The name sign is of internally illuminated letters with opaque sides and white plastic fronts, though some of the letters are partly coloured to give added interest.

2 MIDDLE East Air Line's offices in Piccadilly are intended to serve also as an enquiry bureau for Middle East travel and to stimulate interest in the area. The architects—Farmer and Dark, in association with Assem Salaam—have, therefore, made good use of Islamic motifs in the *décor*. The exterior is finished in white mosaic, the window frame is gold-anodised and there is a panel of Jerusalem tiles, while inside the dominant feature is the pierced vaulted ceiling lit from above by "Northlight" fluorescent lamps. A row of downlights light the window area; a group of eight low-wattage lamps form a ring around a column and give



The Czechoslovak travel bureau. The panels carrying the word "Cedok", the canopy over the counter and the screen behind it are internally lit, while the white mosaic counter front is lit by fluorescent lamps concealed by the black pelmet but shining through glass panels set in the counter top.

Left and centre, the Middle East Air Line's offices, with their appropriately exotic décor. Note the purdah screen partly concealing the office of the manager's secretary, and the antique lamp hanging over the brass-topped occasional table. Bottom, the long counter of the Air France offices, strongly resembling the company's bureau in the Champs Elysée, Paris.



extra light over the counter; and an antique fitting bought in Beirut, now housing a tungsten lamp, hangs low over a figured-brass occasional table.

3 THE offices in Bond Street of Air France have a long counter down one side, presenting a similar appearance to the airline's offices in the Champs Elysée, Paris. They were designed by Charlotte Perriand, in association with Thomas and Peter Braddock, F/ARIBA. A waiting area adjacent to the long counter features a boomerang-shaped seat with round cushions—developed by Mme. Perriand during a visit to Japan—while a suspended group of posters forms a visual barrier at the entrance to the rear area of the bureau, which is devoted to the booking of seats for long-distance itineraries. In this area, specially designed two-level desks are arranged in echelon, and the black linoleum and white plastic sheeting with which these desks are finished contrasts with the " warm " wood panelling of the walls and the grey-painted acoustic-tile ceiling. To the rear of these desks an aluminium-framed cellular screen partly conceals the manager's office.

The main artificial lighting comes from fluorescent lamps concealed above the false ceiling. Extra lighting over the counter comes from louvred spotlights recessed into the ceiling, while adjustable spotlights light the wall behind the counter, the poster displays and the deep recesses of the rooflights at the rear of the bureau.

Brass and " Perspex " sculpture in the window is lit by eyeball spotlights at floor level; a series of fluorescent lamps, partly hidden by black baffles, provides light over the entrance; and there is an internally-illuminated name sign, the letters having bronze sides and white plastic fronts.

4 NEW premises for Air-India International (architects, Alexander Gibson, FRIBA, and Philip Lucey, ARIBA, of Design Research Unit) occupy a site on the corner of Bond Street and Clifford Street, with the

Right and below, exterior and interior, respectively, of the Air-India International offices. Note the polished copper reflectors suspended over the Indian silver greywood counter, and the saucer-shaped reflector, also of polished copper, fixed to the screen—one of three, this throws light on to the ceiling panels of Indian silk.

main entrance at the junction. There are staff offices behind the public area and additional offices on the sixth floor of the building. Externally, columns are faced with white marble into which, on the walls flanking the entrance, small faceted mirrors are set. Stall risers are of black granite and the window frames are of polished teak. There is a glass fascia, painted red, at door height, incorporating internally-illuminated white lettering. The main fascia lettering is mounted above the shopfront on both frontages, being formed of internally-illuminated letters, with red sides and white fronts, on a white background panel. The entrance lobby is lit by five tungsten units recessed into the soffit, which cause the faceted mirrors in the flanking walls to sparkle.

A flexible display system in the windows, carrying figurines, posters, etc., is lit from above by a continuous lighting trough housing fluorescent lamps concealed by eggcrate louvres. The trough also houses venetian blinds which can be dropped to shield the interior from direct sunlight.

Inside, the ceiling is of hand-woven Indian silks in various colours stretched over timber frames to form an abstract pattern. The panels of silk are hung clear of the darkly-painted structural ceiling to allow heat from radiant panels to reach the interior. Three copper reflectors housing tungsten lamps shine on to the Indian silk, which appears to " glow " against its dark background. The reflectors are each pierced by two small lenses which provide a downward component of light.

The long counter of Indian silver greywood, with leather inserts and front panels, is lit from above by four large polished copper reflectors suspended from the ceiling, each housing a circular fluorescent lamp concealed by concentric louvres. A large mural by Prof. Bendre and decorative plaques by Mr. Husain on the screen behind the counter are lit by tungsten spotlights with spun-metal reflectors.

Contractors and suppliers

1 Installation, Lyton Electric Co. Specially designed fittings made by Stewart Fraser Ltd.

2 Installation and manufacture of specially designed fittings, Haskins. " Northlight " fluorescent lamps, Thorn Electrical Industries Ltd.

3 Installation and supply of fittings, Harris and Sheldon (Electrical) Ltd.

4 Lighting fittings made by Oswald Holman Ltd., Courtney, Pope (Electrical) Ltd., and Merchant Adventurers of London Ltd. Sign by Pearce Signs Ltd.

LIGHTING THE RETAIL STORE.......2

Boots—the chemists; chief architect, C. St. C. Oakes, M.B.E., F.R.I.B.A; chief illuminating engineer, J. R. Just

THE Boots empire was founded by Jesse Boot, who in 1863 started to work in the family herbalist business in Goose Gate, Nottingham. His father had just died and young Boot was only 13 years old. It soon became apparent, however, that he had bold ideas on trading methods that were to revolutionise this branch of retailing.

In the window of the Goose Gate shop Jesse placed a notice—" Drugs and Proprietary Articles at Reduced Prices "—and this has been the policy of Boots ever since. In recent months they have been commended in those highly critical publications *Which* and *Shoppers' Guide* for the low prices of their common medical and toilet preparations, as compared with similar products marketed under proprietary names.

The first Boots' branches outside Nottingham were in Lincoln and Sheffield, and in 1883 the firm was registered as a limited company. In 1888 Boots Pure Drug Co. Ltd. was formed and at the same time the organisation started to manufacture many of the drugs which it was selling through its retail branches.

Today the company has over 1,300 branches and is, numerically, the largest chain store in the U.K. It serves annually no fewer than 360 million customers; prepared last year 35 million prescriptions, and has a staff of 37,000, of whom 24,500 are employed on the retail side.

The organisation has in the past had some impact on the architectural world, and its glass-clad Beeston factory has become a classic example of construction in reinforced concrete, with its mushroom-shaped columns eliminating the need for the usual grid of floor beams. Another noteworthy building is the warehouse extension at Island Street, Nottingham, overlooking the canal.

Among Boots' many branches there are of course a substantial number of premises of exceedingly out-moded design, with dark-brown

linoleum floors and plum-coloured mahogany counters. Lighting in these branches is generally quite inadequate by modern standards, giving on average an illumination level of only 8-9 lm/ft^2, and the company is engaged on an extensive programme of re-lighting schemes, coupled in many instances with schemes of redecoration and refurnishing. In charge of this re-lighting programme, as well as responsible for the lighting of the many new branch premises now being built—notably in the rebuilt areas of the blitzed cities and in the New Towns—is J. R. Just, the company's Chief Illuminating Engineer, who works in close collaboration with the company's Chief Architect, C. St. C. Oakes, MBE, FRIBA.

In general, Boots' lighting problem is to provide good overall illumination and to draw customers' attention to showcases and counters—to boost impulse sales. A large number of items are often displayed in a relatively small space and the problem does not resemble that of, say, the gown shop where a few items may be spot-lighted and the rest of the premises left comparatively dark—for contrast or dramatic effect.

Only for jewellery displays is local lighting used—by fittings with perforated spun-metal reflectors mounted directly on the counters. Illumination levels range from 22-24 lm/ft^2 in the smallest branches to 35-40 lm/ft^2 in the largest. As economy has to be borne in mind in stores where the average transaction is for a relatively small sum of money, care is taken that these levels should be achieved with electricity consumption not exceeding 3.5 watt/sq ft, including the consumption of lamps used to light showcases, etc.

For purposes of classification the architect's department divide the branches into three groups: small (the simple chemist shops); medium (the larger shops); and large (the departmental stores). For the small shops a simple pendant fluorescent fitting has been designed, which is unusually shallow and has a one-piece moulded "Perspex" cover with solid ends.

In medium-sized branches a combined tungsten and fluorescent pendant fitting is often used (see Fig. 3). It has glass sides and solid ends. The fluorescent lamps—along the outer edges of the fitting—are concealed by metal louvres, while the tungsten component is provided by two lamps in perforated spun-metal reflectors, without louvres. To economise in consumption the tungsten lamps can be switched off independently.

In large branches lighting is "tailor made" to satisfy the local requirements, depending partly on the class of the locality and—particularly in old premises—on the plan, structure

Opposite page: Fig. 1, ground floor of Exeter branch, looking toward staircase seen in detail in Fig. 2 (above). The Rotterdam ceiling consists of a 4-ft. 3-in. square timber grid suspended from the structural ceiling above. The compartments of the grid are filled with interchangeable lighting units (both tungsten and fluorescent), hardboard panels painted in light colours, and timber louvres concealing smoke-detection units. Peripheral lighting, at a lower level, is provided by fluorescent fittings. Note the double-sided showcases on the half landing of the staircase: illuminated at night, they can be seen from the street. Below, Fig. 3, combined fluorescent and tungsten pendant fitting used in most medium-sized branches for good colour rendering.

Above, Fig. 4, special treatment at Boots' Southampton branch, where suspended canopies house cold-cathode lamps, concealed by "Perspex" louvres and flanked by rows of 150-watt tungsten lamps in metal reflectors with perforated rims. The true ceiling above is painted dark midnight blue. Below, Fig. 5, Rotterdam ceiling at Crawley branch. Here, peripheral lighting is sufficiently high above eye level to permit the use of tungsten fittings—150-watt lamps in fully-recessed downlights.

and architectural character of the building itself. In general, however, pendant fittings are avoided and the current trend is toward some form of Rotterdam ceiling (see Figs. 1 and 5). This, it is claimed, is no dearer in first costs than a normal ceiling with ordinary lighting fittings, when the cost of plastering the soffit of the normal ceiling is taken into account. In new buildings there is, however, the cost of the extra height of the building required to accommodate the Rotterdam ceiling, while in old premises such an arrangement is possible only if existing ceiling heights are adequate.

Some of the grid compartments (usually about 4 ft. square) are filled by lighting units with moulded "Perspex" covers, and it is of interest in this connection to note that by using "pin point" pattern "Perspex" four fluorescent lamps will do the work of the six that would be required with opal "Perspex". (It is true that when the lamps are switched off they can be seen through the cover, but as they are very seldom, if ever, "off" during shopping hours, this can hardly be considered an important disadvantage!) Other compartments of the grid are filled with panels of painted hardboard (some with tungsten downlights recessed into them) and both these panels and the fluorescent lighting units are interchangeable.

At one branch (at Yeovil) a 2-ft. grid has been used and, because of the awkward plan shape, the grid has been set at 45 degrees to the main axis of the premises. Two further developments of Boots' use of the Rotterdam ceiling should be mentioned. The first—at Harlow—com-

prises a "grid" the compartments of which vary in shape and size to create an abstract pattern, with the in-filling consisting mainly of pastel-coloured hardboard panels. Superimposed on this is the regular pattern of the lighting units which house both fluorescent and tungsten lamps (see Fig. 8). The second development is at Liverpool, where the compartments of the grid are octagonal instead of rectangular.

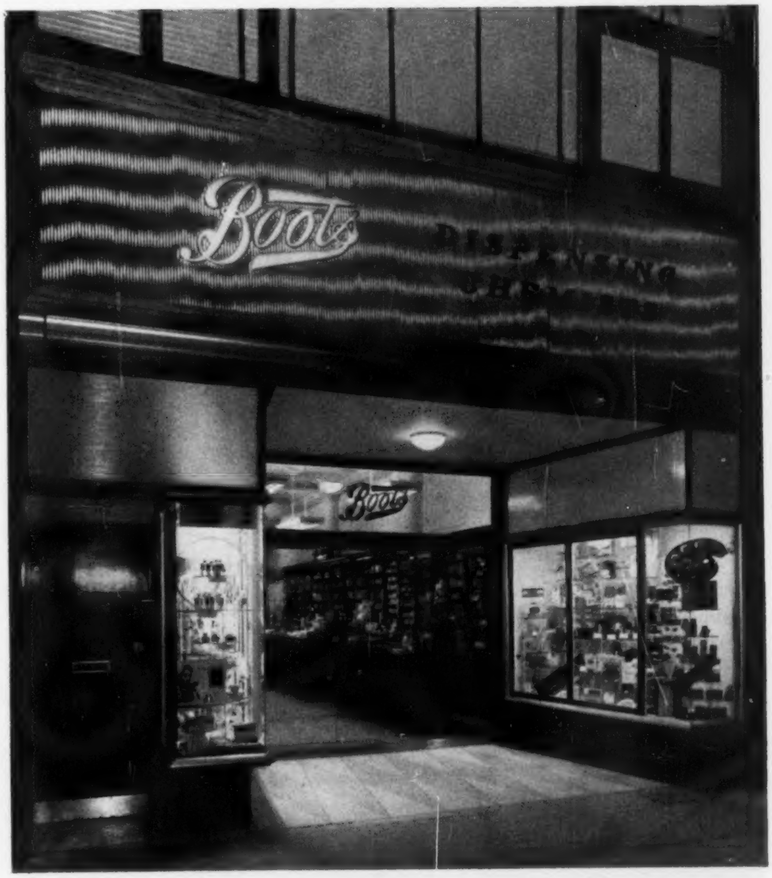
In most branches with a Rotterdam ceiling on the main sales floor counters around the periphery are lit by louvred tungsten downlights recessed into a canopy or, where the canopy is rather low, by "Perspex" covered fluorescent fittings alternating with tungsten downlights. This arrangement serves to concentrate customers' attention on the counters, but in some branches it has not been entirely successful. If they have just left a store with a brightly lit ceiling, customers may, in premises where the ceiling above the counter is not directly lit, find the effect slightly gloomy.

Display Lighting

Wall displays are lit by fluorescent lamps concealed by plywood pelmets, with the names of the departments cut out so that the light shines through (see Fig. 3). The pelmets are interchangeable to allow for changes of layout within the store. In early post-war schemes vertical members of the display cases also concealed fluorescent lamps, but this needlessly complicated arrangement has been given up.

Where, for economy or other reasons, the Rotterdam ceiling cannot be used, rows of fluorescent fittings are recessed into the ceiling, alternating with louvred tungsten downlights. The fluorescent fittings have moulded "Perspex" covers, egg-crate louvres having been rejected because of the difficulty of keeping them clean. In at least one branch these rows of fittings have been placed diagonally across the premises.

Warm-white fluorescent lamps are used throughout. In combination with tungsten lamps and with colour schemes designed for their reflective qualities, this is said to give better



Top, Fig. 6, special treatment at Stevenage branch, where a large lantern light is concealed by 3-ft. deep wooden baffles painted white on one side and pink on the other to add warmth to the natural light. For artificial lighting, 8-ft. fluorescent lamps have been fixed to the soffit of the lantern. Above, Fig. 7, new type of fascia at Knightsbridge branch. It comprises runs of cold-cathode tubing behind two panels of reeded "Perspex" angled to create changing patterns of light. The name sign is in red "Perspex" with gilt edging.

colour rendering than "colour-corrected" lamps for the thousands of different products displayed in the larger Boots' branches and the variety of colours of these products and their packs. It is of interest to note that, with a predominantly female sales staff, particular attention is paid to the lighting of the well-furnished rest-rooms and powder rooms. In the latter the lighting (a combination of fluorescent and tungsten) is arranged so that the girls' make-up will appear in the sales area exactly as it appears when it is applied.

Special Solutions

While the various "standard approaches" described above account for a good deal of the work of the department, Boots try to avoid using similar schemes for branches in the same locality, and special schemes are developed also for branches where a special problem has to be solved. Thus, at Stevenage, the entire shop is covered by a massive lantern light. To conceal this and to add warmth to the lighting a row of 3-ft.-deep baffles was fixed across the full width of the premises, painted white on one side and pink on the other (see Fig. 6). Above the baffles are pairs of 8-ft. fluorescent lamps.

Window Lighting

Window lighting is usually by standard batten units made in various lengths from 2ft. to 6ft. They comprise 4in. x 4in. channels housing the control gear and alternate 80-watt h.p.m.v. and 150-watt tungsten lamps, in silvered-glass reflectors, wired up for connection directly to the mains supply. Window dressing is relatively simple and calls mainly for good general lighting rather than dramatic effects. Instead of competing with adjacent shops by using ever higher intensities, Boots are experimenting with coloured backgrounds to attract attention to their window displays, using red, blue and green lamps on dimmer-controlled circuits.

Fascias are usually of grey "Perspex", with the firm's name in its characteristic script in red moulded "Perspex" lit from behind by cold cathode tubing. (The aim is to emphasise the "shape" of the word rather than the individual letters.) Subsidiary illuminated signs have cut-out letters of white "Perspex".

A new type of fascia that Boots have tried out at their Knightsbridge branch is of interest. The word "Boots"—in red "Perspex" with gilt edging—is set against a background consisting of two layers of reeded "Perspex" sheeting set at slight angles to the vertical (see Fig. 7). As one walks past the store the pattern of light from the cold-cathode tubing behind the fascia constantly changes and scintillates.

Fig. 8, Harlow—one of Boots' most recently completed branches. The ceiling is in the form of an abstract grid in various light colours. Lighting is provided by 8-ft. and 5-ft. fluorescent lamps and 100-watt tungsten lamps, the metal reflectors for both types of lamp being arranged to form a regular pattern, echoed by the pattern of the flooring.

Trends and Developments in Discharge Lamps

By H. G. JENKINS,*
M.Sc., F.Inst.P.

Developments in discharge lamps have been so numerous that it is timely to review recent progress and perhaps to see what the future is likely to bring forth. This article sets out to do this both for the benefit of the lighting engineer and of the user. In addition to the more important discharge lamps, electro-luminescence and the radio-active lamp are discussed.

Electric discharge lamps are no longer strange devices accepted by the adventurous few because of their novelty: they are part and parcel of our existence. Unlike the ordinary tungsten filament lamp, which most people think they understand, the mechanism of light production by the electric discharge and the use of luminescent materials as frequency changers of electro-magnetic radiation, are still not well understood by the users.

The purpose of this article is not to try to remedy this state of affairs, since many good articles and books on the subject are available, but rather to point to recent trends and developments in the more important types of discharge lamps. Where it has seemed necessary for a proper understanding of the development under discussion, certain basic matters are discussed in some detail. Because of their topical interest, sections dealing with electro-luminescence and the so-called radio-active lamp have been included, although, strictly speaking, these are not discharge lamps. In their present stage of development neither of these light sources are likely to make any serious impact in the illuminating engineering field.

In the fluorescent lamp, apart from excellent progress in life and efficiency, the main new matter of interest to report lies in the attempts to increase the wattage loading above the 16 watts per foot used for the British 5 ft. 80-watt lamp; the technical problems in doing this are discussed. A number of other aspects of fluorescent tubes, such as colour trends, colour matching, reflector tubes and cold cathode tubes also receive some mention.

There is not a great deal which is new on the circuit side but a new circuit development, mainly of interest in transport lighting, is described, which is concerned with the use of crystal valves or transistors for producing a.c. from low voltage d.c. supplies.

Great strides have been made in the colour correction of HPMV lamps and these sources are likely to grow in importance for both interior and exterior lighting. It is now technically possible to make a lamp of this type giving white light of a quality comparable with the best fluorescent tubes and it may be thought that herein lies the real answer to the problem of highly loaded fluorescent tubes.

The xenon arc is in some ways a most attractive light source, but because of the technical problems in its operation it has not come into use except for rather special lighting applications. The present state of development of the lamp is discussed.

Perhaps one of the most surprising trends in the lighting field is the rapid growth of sodium street lighting in this country. All are agreed on the poor colour characteristics of sodium lamps; there is equally no doubt about the preference among drivers for sodium lighting, which may well be due in some measure to the monochromatic nature of the light. The main developments in the sources themselves have been concerned with lamp design and the more important developments are discussed.

Performance of Normal Fluorescent Tubes

In the field of normal fluorescent tubes the story is one of continuous progress in performance. Since the introduction of the fluorescent tube almost 20 years ago there has been a steady improvement in luminous performance which, for the 5 ft. 80-watt Daylight tube, amounts to some 70 per cent in initial efficiency and a much greater gain, probably nearer 150 per cent, in average-through-life efficiency. There is little doubt that the very high luminous performance of present-day fluorescent tubes is in a large measure due to the discovery at Wembley in 1942 of halophosphate phosphors, which are now universally used for high efficiency fluorescent tubes. There has been a steady improvement in the intrinsic luminescent efficiency of the halophosphates since their discovery. It has also been recognised that the luminescence of the crystallised particles of less than a few microns in size is poor and that the elimination of such particles from the powder would improve lamp efficiency. Applying modern methods of particle size classification has made it possible to reduce the proportion of very small particles in the powder and has resulted in substantial lamp efficiency gains.

Early failures are now almost unknown and some manufacturers have sufficient confidence in their product to offer to replace free of charge any lamp failing before 3,000 hours or a year's burning. This excellent life performance is brought about by extreme care at every stage in the manufacture.

There are two important colour characteristics of fluorescent tubes: the colour appearance of the tube when alight, which is expressed in terms of co-ordinates in the

* Research Laboratories of The General Electric Co., Ltd., Wembley, England.

CIE chromaticity diagram, and the colour rendering, which is measured by the luminance in eight spectral bands covering the visible spectrum from 3800 Å to 7600 Å. A part of the chromaticity diagram is reproduced in Fig. 1, which shows the chromaticity co-ordinates of a black body emitter at different temperatures. Plotted on the diagram are the co-ordinates of the white fluorescent lamps, which have evolved and which are now in common use. Points defining the colour appearance of both normal and low temperature incandescent filament lamps are also included for comparison.

It is possible to reproduce in fluorescent tubes almost any white colour appearance desired. The colour rendering characteristics can also be varied over a wide range. Following a period of experimentation, it is pleasing to report that there is now a marked trend throughout the world towards three colours with co-ordinates not far from the colour temperature points 6500°K, 4200°K and 2300°K. A white colour with co-ordinates not far from those of the 3500°K point has been used in this country for cold cathode fluorescent tubes for several years. A similar colour finds some applications in normal fluorescent tubes; it is, perhaps, surprising that the use of this excellent colour in the USA, where it was at one time very popular, is on the decline.

In practice there is a trend towards two types of spectral distribution in each of the three main colour regions: a high efficiency lamp with a colour suitable for most general lighting purposes, and a lamp of better colour rendering characteristics for applications where colour rendering is more important than very high luminous efficiency, the so-called deluxe lamp. It is interesting to note that in this country and in the USA probably less than 5 per cent of the fluorescent lamps in use are of the deluxe type. In Europe the percentage is much larger and may even be as high as 40 per cent. It is not easy to understand the reasons for this difference in practice.

Table 1 indicates the luminous characteristics of the established high efficiency and deluxe white tubes. The luminous values given are for guidance only: some manufacturers claim higher figures, other achieve lower values. The precise colour quality obtained can affect the luminous output in a marked manner, as is evidenced by comparing the outputs of normal and deluxe colours. A reduction in the filling pressure of the carrier gas gives an increase in the luminous output but also affects the lamp life adversely. It should also be observed that the best average-through-life output, which is after all what really matters to the user, is not necessarily associated with the best initial performance.

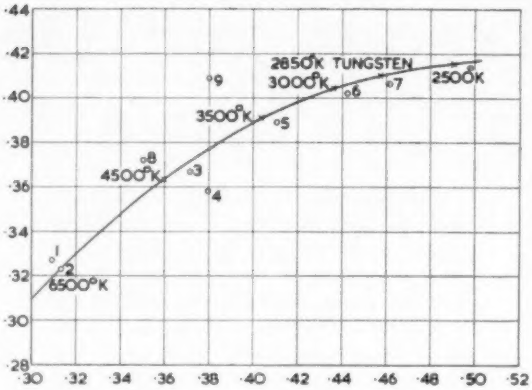


Fig. 1. Chromaticity coordinates of fluorescent lamps.

Table 1

Luminous performance of high efficiency and de luxe fluorescent tubes

Approximate colour temperature region	Colour quality	Name of colour	Approximate luminous output—4 ft. 40-watt lamp*	
			100 hrs.	Av. 5,000 hrs.
6,500°K	High efficiency	International Daylight	2,280	2,040
	De luxe	Colour Matching or Northlight	1,840	1,600
4,200°K	High efficiency	British Daylight or Cool White	2,680	2,440
	De luxe	Natural or De luxe Cool White	1,920	1,680
3,500°K	High efficiency	White	2,720	2,480
2,800°K	High efficiency	Warm White	2,600	2,360
	De luxe	De luxe Warm White	1,680	1,440

* The output of the British 5 ft. 80-watt lamp is rather less than 1.9 times these values. The average-through-life output is about 85–90% of the initial values depending on colour.

Highly Loaded Fluorescent Tubes

It is well known that the luminous efficiency of a fluorescent lamp is largely determined by the amount of mercury ultra-violet radiation at 2537 Å which reaches the fluorescent coating. It is a characteristic of this radiation that it is absorbed by the unexcited mercury atoms in the discharge space which may re-emit the absorbed energy as ultra-violet radiation. A quantum of 2537 Å radiation in a fluorescent tube may be absorbed and re-emitted many times in its passage to the fluorescent coating. This increases the probability that it will lose its energy by collision or some other non-radiative process in the discharge and never reach the coating. The number of times the quantum is absorbed and re-emitted depends on the concentration of mercury atoms in the discharge space or, in other words, on the mercury vapour pressure, as well as on the distance it has to travel from its point of origin to the fluorescent coating.

The intensity of 2537 radiation is also a function of the electron energy or electron temperature in the discharge. Increasing the current density in the discharge lowers the electron temperature and with it the efficiency

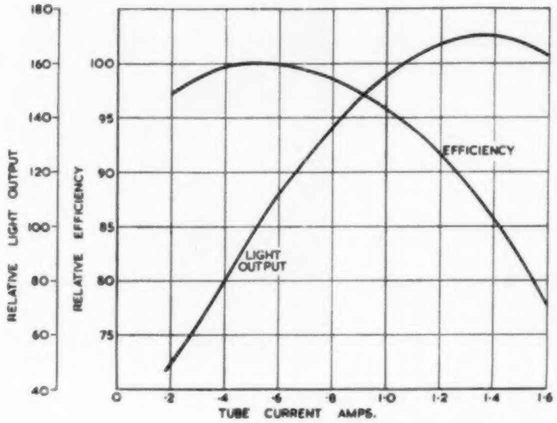


Fig. 2 (left). Variation of luminous efficiency and output of 5 ft. × 1½ in. fluorescent tube with mercury vapour pressure and arc current density.

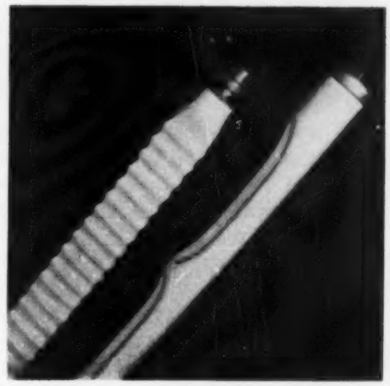


Fig. 3 (right). Highly loaded fluorescent lamps using specially shaped tubing.

of production of 2537Å radiation and the luminous efficiency of the fluorescent tube. Thus, high mercury vapour pressure and high current density both lead to reduced efficiency. This is illustrated in Fig. 2, which shows the way in which the luminous efficiency and output of a 5 ft. x 1½ in. fluorescent tube vary with mercury vapour pressure and arc current density.

It is clear from these curves, which were obtained at normal room ambient temperature of 20°C, that the lamp loading for maximum efficiency is not far from 10 watts per foot. This is the loading of the high efficiency 4 ft. 40-watt lamp used throughout the world. The most important British lamp, the 5 ft. 80-watt rating, has a loading of 16 watts per foot, which was, until recently, the maximum loading used for fluorescent lamps anywhere. This probably represents the best compromise between luminous efficiency and electrical loading and following the considerable success of the British 5 ft. 80-watt lamp, lamps of closely similar loading were marketed in the USA a few years ago.

More recently, two types of fluorescent tubes dissipating about 25 watts per foot have been marketed in the USA[1, 2]. In one of these a tube of large surface area is used, which ensures that the tube wall temperature, and hence the mercury vapour pressure, does not rise to too high a value. If the large surface area were obtained merely by increasing the diameter of the tube, the tube voltage would be low and the increased wattage could then only be obtained by operating at a high current density with resultant poor efficiency. To avoid this, the large tube has a series of lengthwise grooves or depressions separated by short lengths of the original circular section tubing to give increased mechanical strength. The effect of the grooves is to increase the electron temperature in the discharge through increased losses of positive ions at the tube wall. Another effect of the grooving is to shorten the distance the ultra-violet radiation has to travel from its point of origin to the fluorescent coating. This reduces the losses due to absorption of the radiation in the mercury vapour.

Fig. 3 shows part of an American grooved lamp compared with an experimental lamp of elliptical cross-section

Table 2

Comparison of normal and highly loaded fluorescent tubes

Type of Tube	Tube length ft.	Tube diam. ins.	Gas filling and pressure	Tube wattage	Watts per ft.	Tube volts	Tube current amps.	Initial lumens approx. (Warm White)
Normal 4 ft. 40-watt	4	1.5	3 mm.A.	40	10	105	0.45	2,600
British 5 ft. 80-watt	5	1.5	3 mm.A.	80	16	101	0.89	5,040
British 8 ft. 125-watt	8	1.5	3 mm.A.	125	app. 16	152	0.96	8,125
American grooved	4	2.1	1.4 mm.A.	100–110	25–28	84	1.5	6,200
American controlled vapour pressure	4	1.5	2 mm.Ne.	100-110	25-28	99	1.21	6,200
British experimental highly loaded	5	1.5	2 mm.A.Ne.	125	25	125	1.2	7,400*

* The average output over 5,000 hours is about 80% of this value.

developed at Wembley. The surface of the latter is corrugated to improve its mechanical strength. Both these lamps use the same carrier gas filling (about $1\frac{1}{2}$ mm argon) and have similar electrical and luminous characteristics (see Table 2).

The second type of American highly loaded lamp uses circular cross-section tubing of normal dimensions. To overcome the difficulty of excessive mercury vapour pressure, which would arise from the higher tube wall temperature, use is made of the well-known fact that the saturated vapour pressure in an enclosure is determined, not by the highest or average temperature of the enclosure, but by the temperature of the coldest part. In the tube in question this is the region behind the electrode which, by the use of a metal disc immediately behind the electrode which acts as a heat reflector, is arranged to operate at a temperature some 20°C lower than that of the body of the tube. To avoid the low tube voltage associated with the usual argon carrier gas under conditions of high loading, this controlled vapour pressure lamp uses a carrier gas filling of neon or a neon-argon mixture. The characteristics of various types of highly loaded lamps are given in Table 2, together with those of normal fluorescent tubes for comparison.

In this country and in Europe work has been going on in the laboratories of the leading lamp manufacturers on the problems associated with high loading. Lamps of the controlled vapour pressure types described above have been used for certain special purposes and other types have been shown in their experimental forms at exhibitions. One of these, developed at Wembley, is similar in dimensions to the 5 ft. 80-watt lamp but rated at 125 watts. This uses a new type of end cooling arrangement which eliminates the sharp shadow produced by the metal heat reflector, which is a feature of the American construction. It also has a mixed carrier gas (neon-argon) which gives the required electron temperature and avoids the serious life problems associated with a pure neon filling. It is understood that the American controlled vapour pressure lamp now uses a mixed gas filling. Provisional characteristics of the experimental British lamp are included in Table 2. The objective life of the latter tube is approximately 5,000 hours.

The increased energy in the discharge, coupled with the reduced filling pressure and special nature of the carrier gas, introduces considerable problems in connection with life and lumen maintenance in these highly loaded lamps. It may at least be questioned whether in their present state of development the lamps can be considered as giving any economic or other advantages, except perhaps for a few special applications, over the well-tried 5ft. 80-watt lamp widely used in this country.

Fluorescent Reflector Tubes

It has been known for many years that the luminance of discharge tubes can be increased by applying a specular reflecting surface to the back half of the tube; some early neon signs were constructed in this way. More recently it has been proposed to apply a diffuse reflector between the coating of a fluorescent lamp and the glass tube[3]. A fluorescent lamp with a reflector of this type was described recently[4] and marketed in this country in 1956.

Table 3

Characteristics of 5 ft. 80-watt normal and reflector tubes

Rating	Tube	Efficiency (lm/W) Warm White	Light output (Lumens)	Brightness (Cd/sq. in.)	
5 ft. 80-watt	Normal	63	5,040	5.9	
				Window	Reflector
5 ft. 80-watt	Reflector Type	57	4,560	11.8	2.1

In this the glass tube is first coated internally with a thin uniform layer of titania, which has a high reflection factor for both ultra-violet and visible radiation. A strip of the titania coating the whole length of the tube and about one-third of the circumference in width, is removed before applying the fluorescent coating on top of the titania reflector coating. This strip serves as a window through which about 90 per cent of the light from the tube is emitted. Most of the remaining light passes upwards through the coated reflector. The characteristics of a 5 ft. 80-watt reflector lamp are given in Table 3.

It will be clear that a deposit of dust or dirt on the reflector will cause much less loss of light than it would do in a normal tube. For this reason the fluorescent reflector tube is finding useful application in situations where, because of the surroundings, it is difficult to keep the tube clean. The writer has seen reflector lamps used for lighting large offices with the window pointing up to the ceiling. It was stated that the office staff had insisted on this method of burning the lamps to reduce glare. This particular method of using reflector lamps is, perhaps, one which neither the lamp manufacturer nor the illuminating engineer envisaged. It is to be hoped that people who are misguided enough to use naked fluorescent lamps in their shop windows will take note of this and replace them with reflector tubes operating with the reflectors facing the street.

Caps for Fluorescent Tubes

For reasons which are well understood, the British 5 ft. 80-watt lamp was introduced with a bayonet cap, which is cheap, mechanically strong and electrically safe. It has, however, been criticised because the cap and holder combination is somewhat clumsy, does not permit close end-to-end mounting of tubes and takes up too much room in the fitting. The bipin cap was subsequently adopted in the British market for other ratings, in line with practice abroad. This cap has never been regarded as entirely satisfactory for long lamps and the British 8 ft. lamp was introduced with bayonet caps.

In an article early this year[5] a new type of cap with recessed double contacts is described, which, it is claimed, overcomes the disadvantage of both the bayonet and bipin caps. This cap is closely similar to and is fully interchangeable with one introduced in the USA for lamps with low voltage cathodes and is being used increasingly there.

The recessed double contact cap and holder are shown

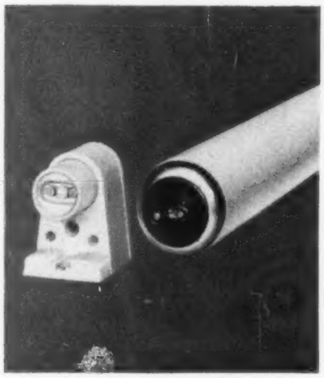


Fig. 4 (left). Recessed double contact cap and holder for fluorescent tubes.

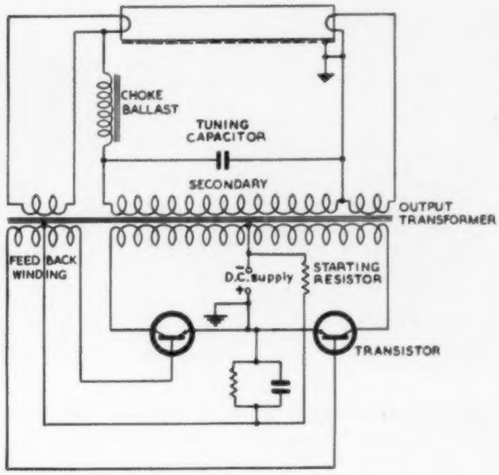


Fig. 5 (right). Transistor inverter circuit for operating fluorescent tubes from low voltage d.c. supplies.

in Fig. 4. It is being fitted to some British 8 ft. lamps and if experience with it is satisfactory it may be used on new types of lamp, for example, the highly loaded lamps. Because of its high cost it is unlikely to replace the bayonet cap on the 5 ft. 80-watt lamp, particularly since this lamp has recently been marketed with the familiar bipin cap. An 8 ft. lamp with a bipin cap was also introduced on the British market last year, so that this lamp is now available in this country with three types of cap.

Fluorescent Tube Circuits

There have been no major changes in fluorescent tube circuits in recent years. The use of the so-called starterless circuits, with indirect filament heating arrangements, seems to be increasing, although perhaps rather slowly. Factors which have mitigated against their use are: the higher cost of the control gear; the higher cost of the special striped lamp; the reluctance of large users who are already equipped with switch-start lamps and circuits to introduce a circuit calling for a special lamp.

Considerable progress has already been made in bridging the gap between the control gear costs for the two arrangements. The second and third difficulties mentioned above are likely to be removed by the introduction in November of a universal 5 ft. 80-watt striped lamp suitable for both switch-start and starterless circuits. The marketing of this lamp at the same list price as the unstriped lamp is an important step forward; it has been made possible by the development of a new striping technique which lends itself to mass production methods[6]. It is to be expected that in these new circumstances the use of starterless circuits will increase rapidly, if only because of a growing appreciation among large users of the simplified maintenance problem arising from the elimination of the expendable starter switch.

In the USA some economy in the design of switchless start control gear has been achieved by introducing lamps with small, 3 volt, cathodes. Lamps of this type have not been used to any extent in this country and it may at least be questioned how far the small advantage associated with the change in cathode design would be justified in this country in view of the trend towards a universal tube for both switch-start and starterless circuits.

Sequence start circuits, which enable two tubes to be operated in series from normal supply mains, appear to be on the increase in the USA. The circuits offer some advantages in economy, particularly on 110V supplies, but do not appear to have come into use in this country or in Europe to any extent.

Despite the favourable reports on operation at frequencies higher than usual[7], there seems to be no economic or other worthwhile advantage to be gained by such operation where normal power supplies are available. For certain forms of transport lighting the situation is different and higher frequency operation (up to 1,000 c/s) is finding increasing application. The greatly reduced size and weight of the control gear which high frequency makes possible is obviously of prime importance in aircraft lighting.

An interesting new development is the crystal valve inverter circuit for providing a.c. from d.c. without the need of any moving parts[8]. The circuit of a typical transistor inverter to operate a single hot cathode fluorescent lamp from a low voltage d.c. supply is shown in Fig. 5. The inverter, which uses two germanium P-N-P power transistors, consists of a self-driven push-pull oscillator, the driving power for which is obtained from a feed-back winding on the output transformer. A parallel resistance-capacitor network in the feed-back circuit controls the drive power. The fluorescent lamp is operated in a switchless start circuit which uses a choke ballast. A suitable alternating voltage for the lamp circuit is derived from the transformer secondary winding and two further windings provide uncompensated pre-heating of the lamp cathodes. The lamp circuit is tuned by the capacitor connected across the secondary winding; this, together with good choke design, ensures both a secondary voltage and lamp current of sinusoidal waveform.

With the transistors at present available, inverters of this and similar types have been designed to operate lamp loads of up to 40 watts from 12V and 24V d.c. supplies, with overall efficiencies of about 65 per cent and operating frequencies between 1 Kc/s and 10 Kc/s. The precise frequency is largely influenced by the tuning capacitor. Fig. 6 shows a complete unit.

Modifications of this circuit in which the inverter provides a.c. for filament heating enable as many as eight

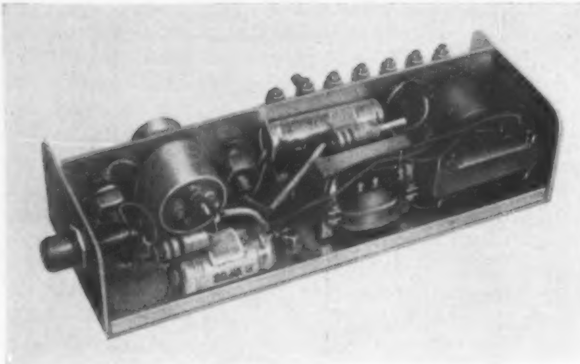


Fig. 6 (left). Transistor inverter unit. (Actual length 8 ins.)

Fig. 7 (right). Industrial colour matching unit.

15-watt fluorescent tubes to be operated in series from a 600V d.c. supply for train or bus lighting.

Cold Cathode Fluorescent Tubes

Cold cathode fluorescent tubes continue to find application for many types of lighting, particularly where long trouble-free tube life is important. It is of interest that sensitised cold cathodes are used widely abroad for these long high voltage tubes and to a much smaller extent in this country. Most of the tubes in this country use plain unsensitised electrodes and this practice appears to have been fully justified by the exceptional life performance: tube failures before 20,000 hours are almost unknown. This has made it possible to obtain increased luminous output by increased tube loading. Thus, using a modified gas filling and operating the tubes at 150 mA instead of the usual 120 mA an increase in luminous output of about 25 per cent has been achieved.

The usual fluorescent tube colours are available in cold cathode tubes at efficiencies somewhat lower than obtained with hot cathodes. Table 4 gives the luminous characteristics for 9 ft. lighting lengths dissipating about 70 watts. These tubes are often used outdoors and to overcome the " mercury starvation " which occurs in cold weather, a new type of electrode construction is used. In this a reservoir of mercury is trapped behind the electrodes, the heat from which distils the mercury into the discharge.

New Source for Industrial Colour Matching

As pointed out in a paper presented to the IES in 1956[9], many industries such as textile dyeing, colour printing, paint and paper making use visual comparison of a coloured sample with a standard colour as the basis of colour control in their manufacture. Instrumental methods of colour assessment are necessary when measurement of colour is in question, but the high accuracy and speed of a trained industrial colour matcher cannot be equalled by any instrumental method in comparative work.

As a direct result of the study made in the paper referred to, a new colour matching unit of good efficiency and suitable for critical colour matching has been marketed. The unit is shown in Fig. 7. The light sources comprise blue fluorescent tubes, tungsten filament lamps and a source of long wave u.v. radiation for use when comparing colours having a fluorescent constituent.

Great care has been taken to ensure adequate mixing of the different sources on the working surface. Apart from the u.v. lamp, the novel feature of the unit is the manual control which enables the effective colour temperature of the mixed light to be varied. With the aid of dichroic colours which match in daylight, the user is enabled rapidly to adjust the source to natural daylight before commencing matching.

The unit, which dissipates approximately 400 watts,

Table 4

Luminous characteristics of 9 ft. cold cathode fluorescent tubes with unsensitised electrodes

Tube	Lighting Length	Tube wattage	Lumens/ft. (Average over 15,000 hours)	Total lumens (Average over 15,000 hours)
Present 20 mm. diameter	8 ft. 9 ins.	67	300	2,610
Experimental 20 mm. diameter	8 ft. 9 ins.	90	370	3,250

Table 5

Spectral band data for industrial colour matching unit

Waveband (AU)	New colour matching unit	Natural daylight (after J. N. Hull)
3,800–4,200	0.014	0.027
4,200–4,400	0.30	0.21
4,400–4,600	0.59	0.78
4,600–5,100	10.1	10.6
5,100–5,600	47.0	40.4
5,600–6,100	32.6	36.8
6,100–6,600	8.6	10.5
6,600–7,600	0.76	0.77

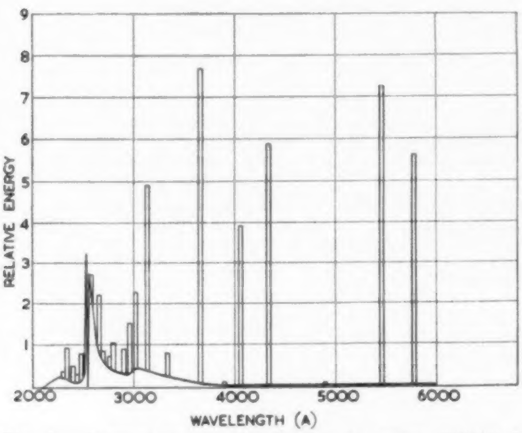


Fig. 8. Spectral energy distribution of quartz HPMV lamp with outer bulb removed.

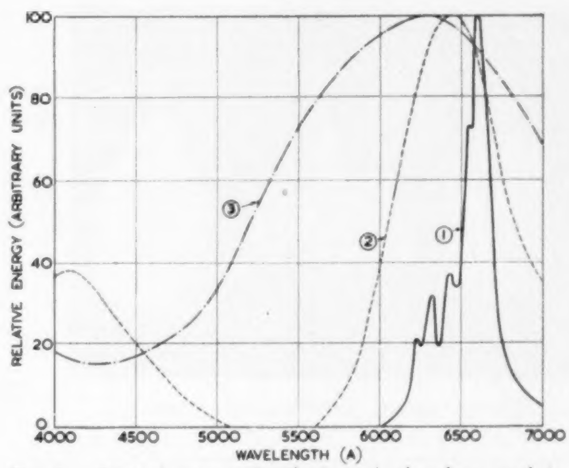


Fig. 9. Spectral energy distribution of phosphors used in HPMV fluorescent lamps.

enables an illumination level of 150 lm/ft^2 to be obtained over the working area, 2 ft. × 1½ ft. Table 5 gives the luminance in the usual eight spectral bands, together with one of the published distributions for daylight (sun plus clear sky)[10]. The figures indicate a satisfactory measure of agreement and suggest that the unit will be entirely suitable for any colour matching work normally carried out under natural daylight conditions.

High Pressure Mercury Vapour Lamps

Increasing the mercury vapour pressure in an argon-mercury discharge up to one or two atmospheres, for example, markedly changes the distribution of energy in the spectrum: more energy is emitted in the visible and less in the ultra-violet region. Nevertheless, as the energy distribution curve in Fig. 8 shows, there is still a considerable amount of energy emitted by an HPMV arc between 2000 and 3800Å, which in the 125-watt lamp in question amounts to about 19 watts. It is not surprising, therefore, that the most important developments in HPMV lamps in recent years have been concerned with the utilisation of the u.v. energy to improve the colour characteristics and the efficiency of the lamp.

Because of the high temperature of the HPMV arc it is not possible to utilise the u.v. energy by applying fluorescent coatings directly to the arc tube: it is necessary to apply the coating to the inside surface of a bulb surrounding the discharge envelope.

The first fluorescent HPMV lamp was marketed in this country in 1937. This had a hard glass envelope which transmitted only the long wave u.v. radiation. Also the phosphors available at that time were highly temperature sensitive and lost much of their efficiency even when coated on to a rather large outer bulb. The degree of colour correction obtained from the fluorescent coating would now be considered as only nominal, but the lamp was regarded as a great step forward and proved useful for many applications where the colour of the plain mercury discharge was unacceptable.

The modern fluorescent HPMV lamp is a direct development of these early lamps: it has been made possible by the discovery of red emitting phosphors responsive to a wide range of u.v. wavelengths and possessing high temperature stability [11, 12, 13]. Used in association with a quartz HPMV lamp, these phosphors give excellent colour rendering with little or no loss in efficiency, or a smaller degree of colour correction with some gain in efficiency. The spectral energy curves in Fig. 9 show the emission spectra of the three most important phosphors: magnesium germanate, barium strontium lithium silicate and strontium zinc phosphate. Magnesium germanate gives a somewhat better correction in the deep red, but because it has a weak absorption band in the blue it tends to accentuate the green emission from the lamp. The silicate phosphor, on the other hand, has a weak emission band in the blue, which gives a whiter colour appearance to the lamp. It is less temperature stable than the germanate and is at present used only in low wattage ratings. Strontium zinc phosphate emits mainly in the yellow-orange region and, as might be expected from the emission curve, gives a gain in efficiency of perhaps 10 per cent as well as some improvement in colour over the plain discharge.

A modification of the germanate-coated lamp has been produced in the USA in which a tinted outer bulb is used to improve the colour still further by absorbing some of the light from the middle region of the visible spectrum[14]. The filter coating on the bulb is pale purple in colour and is obtained by firing a colloidal metallic film on to the inside surface of the bulb, to which phosphor coating is applied in the usual way. Earlier lamps used a pinkish glaze applied to the outside surface of the bulb. Apart from the loss in efficiency involved, amounting to about 25 per cent, this substractive technique has obvious limitations: it cannot add colour, blue for example, in which the lamp is deficient.

Work has been proceeding at Wembley to obtain a still better colour improvement and experimental lamps of 400-watt rating have been produced with colour rendering characteristics equal to those of de luxe colour fluorescent tubes. The arc tubes in these experimental lamps contain vapourisable metals such as cadmium and zinc,

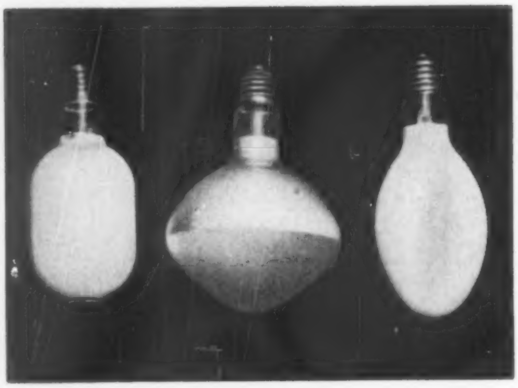


Fig. 10. 400-watt HPMV fluorescent lamps.

the radiation from which fills in the spectral regions in which the normal lamp is deficient. A number of manufacturing and performance problems still remain, but there is considerable prospect that these will be resolved in due course. It seems possible that this important development may provide the illuminating engineer with a new lighting tool of considerable power and scope.

Fig. 10 shows typical 400-watt fluorescent HPMV lamps, including a reflector type first marketed in the USA. In this latter lamp the fluorescent coating is applied on top of a metallic or powder reflector on the bulb. The flat surface of the bulb is left uncoated. Table 6 gives the more important characteristics of some commercially available fluorescent HPMV lamps.

It has been the practice in England to express the red content of fluorescent HPMV lamps in terms of the luminous flux passing through a Wratten No. 25 filter. This, expressed as a percentage of the total lumens from the lamp, is known as the red ratio. The method of assessment is useful provided only one type of phosphor is in question; it can be misleading if lamps using different phosphors are being compared. The weakness of the method is that the filter transmits over a wide range of wavelengths from orange to deep red and the red ratio tells us nothing about the detailed nature of the light transmitted. Another defect is that it does not tell what is happening in the blue or green regions of the spectrum.

There seems little doubt that the method of measuring the colour rendering in terms of luminance in eight spectral bands used for fluorescent tubes or a simplified version of it will be more satisfactory for the new lamps.

Table 6

Typical data for fluorescent quartz HPMV lamps

Type	MBF				
Wattage	80	125	250	400	1,000
Initial lumens	2,960	5,250	11,000	19,000	56,000
Av. lumens through life	2,600	4,600	10,000	17,500	50,000
Red ratio*	Approximately 7%				
Burning position	Any				Vertical cap up
Supply voltage	200/250				350/440

* Red ratio: The percentage of the total light transmitted by a Wratten 25A filter. In lamps without fluorescent coatings it is 1 to 2%.

Table 7 gives typical spectral band measurements on silicate and germanate-coated lamps. The CIE trichromatic coefficients, which measure the colour appearance of the lamps, are indicated in the diagram in Fig. 1.

Sodium Vapour Lamps

Whatever one may think about the colour of sodium light, one cannot fail to be impressed by the remarkable growth in the use of the lamps for street lighting in this country and in Europe. There seems to be an undoubted preference for sodium lighting among car drivers, which is only partly explained by the good levels of illumination which the high efficiency of the lamps makes practicable. It is a curious fact that in the USA, where much of the early development work on sodium lamps was done, they are hardly used at all. This is no doubt due in part to the poor performance of the high-current lamp evolved in the States to suit their series system of street lighting.

The discharge envelope of the 140-watt lamp, widely used here and in Europe, is a tube about 86 cms. in length and 1.8 cms. in diameter, bent in the form of a narrow U for compactness. The tube is filled with about 10 mms. of neon gas containing 1 per cent of argon to assist starting. Globules of pure metallic sodium are distributed throughout the length of the tube during the pumping process.

When first switched on the discharge glows with the characteristic colour of neon, which turns to yellow sodium light as the sodium vapour pressure increases. To conserve the heat of the discharge for this purpose the arc tube is enclosed in a glass jacket which, until a few

Table 7

Typical spectral band measurements on fluorescent HPMV lamps

HPMV lamp and coating	3800–4200A	4200–4400A	4400–4600A	4600–5100A	5100–5600A	5600–6100A	6100–6600A	6600–7600A
125-watts uncoated lamp	0.019	0.73	0.10	1.18	52.1	44.2	1.35	0.29
125-watts silicate coating	0.016	0.65	0.13	1.1	47.2	44.7	6.0	0.28
400-watts germanate coating	0.012	0.465	0.063	0.84	45.2	46.5	6.1	0.80

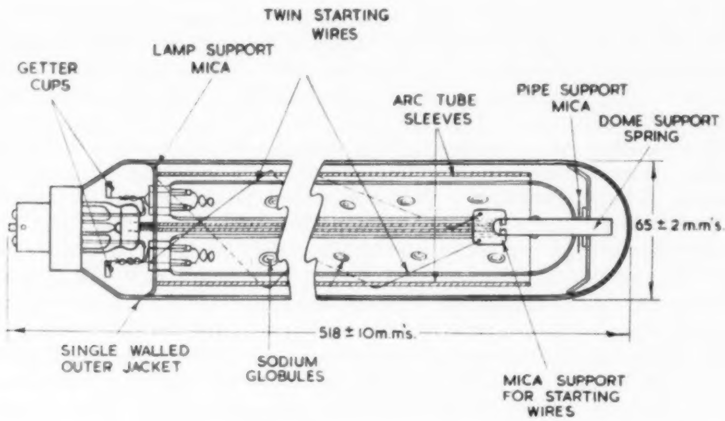


Fig. 11. Constructional features of integral sodium lamp.

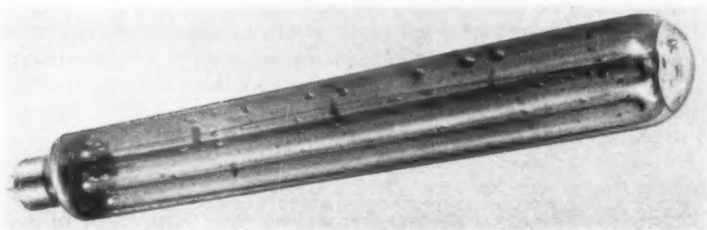


Fig. 12. The new 280-watt sodium lamp.

years ago, comprised a highly evacuated double-walled dewar flask independent of the arc tube.

By far the most important development in sodium lamps in recent years has been concerned with the outer jacket. A new type of lamp has been marketed in which the detachable dewar flask is replaced by a single-walled tubular outer jacket, into which the discharge tube is sealed and the jacket highly evacuated[15]. The high vacuum is achieved and maintained by means of an evaporated layer of barium which is confined near the shoulder of the jacket to avoid obscuration of the light. This integral construction possesses many advantages over the two-part lamp: installation, cleaning and replacement of lamps are greatly simplified and the uncertainty about the condition of the dewar flask is eliminated. The luminous performance of the 140-watt integral lamp is appreciably better than that of the old construction, and since the arc tube is completely protected from the atmosphere difficult starting under high humidity conditions does not arise. Fig. 11 shows the constructional details of the integral lamp. It will be noted that the limbs of the arc tube have closely fitting glass sleeves which serve to reflect heat from the discharge back into the tube.

The integral construction has very recently been used to good effect to produce a 280-watt lamp in which two 140-watt arc tubes are contained in the same outer jacket. Under these conditions heat reflecting sleeves are not required. The four contacts from the lamps are brought out to a substantial 4-pin cap and the lamp has the same dimensions as a normal 140-watt integral type. With its very high luminous output (approximately that of a 400-watt glass HPMV lamp) this new lamp is likely to prove valuable for streetlighting, floodlighting and other applications. The new lamp is shown in Fig. 12. Approximate luminous data are given in Table 8.

Sodium is one of the most chemically reactive metals, particularly when heated close to 300°C, which is the operating temperature of the arc tube. At this temperature normal glass would be attacked and destroyed by the hot sodium vapour, and to protect the discharge tube its inside surface is coated with a thin flashing of a special glass resistant to sodium attack.

This protective layer is an all-important factor in the luminous performance of sodium lamps. The glass in most common use has a sodium aluminium borate composition. A characteristic of the sodium borate glass is its ability to absorb metallic sodium, which shows itself as a brown colouration on the tube after a period of

Table 8

Luminous data on sodium lamps

	Integral and Dewar-Jacket Sodium Lamps				
Wattage	280*	140	85	60	45
Initial lumens	18,900	10,200†	6,200	4,000	2,600
Av. lumens through life	16,800	9,100	5,525	3,420	2,250
Burning position	Horizontal		Horizontal or vertical cap up		
Life	4,000 hours				

* Integral type only.

† The value for the 140-watt Integral lamp is about 10% higher.

operation. There is some loss of light due to this, but this is small compared with the gain obtained by maintaining a uniform distribution of sodium throughout the discharge space during the life of the lamp.

The globules of sodium in a lamp tend to re-distribute themselves during operation of the lamp by a complex process of thermal diffusion arising from the continual evaporation and condensation of the sodium during operation of the lamp. This can affect the luminous performance of the lamp markedly since, after a time, considerable regions of the discharge may be almost completely denuded of sodium, showing permanently the red glow of neon. The only completely effective method known at present of overcoming the effects of thermal migration is by the use of an absorbing glass of the type described above.

Sodium resistant glasses which do not absorb sodium and therefore do not develop a dark colouration are known and are in use. Because of thermal migration these do not give the luminous performance which might be expected from their relative freedom from darkening. Furthermore, these glasses absorb the rare gas filling (particularly the small amount of argon added to reduce the starting voltage) much more rapidly than do glasses of the sodium aluminium borate type. This necessitates special steps to avoid starting voltage trouble due to gas absorption. If the problems of thermal migration and gas absorption can be satisfactorily resolved with such glasses there is good hope of a substantial improvement in the lumen maintenance of the lamps.

Maldistribution of sodium in a lamp can occur from mechanical causes such as vibration or shock while the lamp is hot and the sodium in a molten condition. Various proposals have been made to overcome mechanical migration, such as constrictions in the arc tube, all of which are more or less effective in reducing bulk movement of the sodium. The lower wattage lamp ratings with their shorter arc tubes are less affected by sodium migration, whether it be thermal or mechanical.

Xenon Lamps

The outstanding advantage of the high current arc discharge in xenon at a pressure of the order of an atmosphere is its excellent colour. The spectral distribution of the light is close to that of a full radiator at a temperature near 6,000°K.

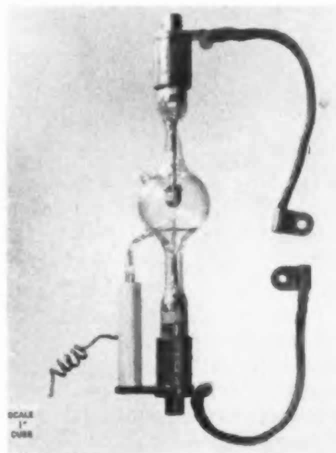
Unfortunately, there are a number of disadvantages which have prevented the xenon lamp from being widely used: the lamp is costly to manufacture; also the arc voltage is low and the current high, and this, associated with a very high starting voltage, leads to bulky and costly control equipment. The luminous efficiency varies between about 20 and 30 lm/W according to the type of lamp. Bearing in mind the excellent colour and the high luminance of the source, this is not unsatisfactory, but since the lamps are usually operated on direct current with a resistive ballast the overall efficiency is very poor.

Development has followed two main lines: the short arc, high luminance lamp for optical projection, which may be filled to a pressure as high as 10 atmospheres measured when the lamp is cold, and a long arc type with lower luminance and filling pressure.

Much work on xenon lamps in recent years has been done in Germany, where a range of excellently finished lamps has been marketed[16]. These include air-cooled compact source types of wattage rating from 160 watts up to 2½ kW and water-cooled linear source types up to 5 or 6 kW. The 160-watt lamp is used fairly widely in Germany as a source for colour matching. The higher wattage compact source types are used mainly for optical projection, particularly film projection. The long arc length lamps are used for stage lighting and similar applications. A 1 kW lamp with an arc length of 120 mms and in a tube 20 mms in diameter has been used in fading test apparatus. A very large lamp in a quartz tube 240 cms long and 5 cms in diameter, dissipating 65 kW at a current of 250 amps has been described[17]. This is no doubt an interesting technical achievement, and it may well prove to have application for certain special purposes, for example, football field lighting.

It is, perhaps, fair to say that the only really important commercial application for xenon lamps is in 16 and

Fig. 13. 2-kW xenon lamp for film projection.



35 mm film projection, where the lamps may well replace the carbon arc. A British lamp for this purpose has recently been described[18]. This is rated at 2 kW and has a life of 1,000 hours. The spherical quartz bulb is filled to a cold pressure of 4 atmospheres, giving about 10 atmospheres when in operation. The arc length is 8.5 mms and the average arc luminance is approximately 25,000 stilb. The lamp is shown in Fig. 13.

Electroluminescent Lamps

It is, perhaps, permissible to make some mention of these devices, although they can hardly be described as discharge lamps. The electroluminescent lamp or panel comprises essentially a layer of a special sulphide phosphor about 0.1 mm thick in a suitable resin sandwiched between two conducting surfaces, one at least of which is transparent. The phosphor glows with its characteristic colour on application of an alternating voltage to the conducting plates. A full account of the phenomenon, together with an excellent bibliography, was presented to the IES in 1955[19].

Since then a great deal of further work has been reported. This has added something to our knowledge of the mechanism of the process, although this is still very imperfectly understood. Luminous efficiencies appreciably greater than about 10 lm/W of green light, corresponding to 2 or 3 lm/W of white light, have not been achieved. Under conditions of high field strength and high frequency, luminances of the order of 100 foot lamberts are possible but the life and lumen maintenance of the panel under these highly loaded conditions are very poor.

It seems clear that unless unexpected improvements occur, electroluminescent panels cannot be regarded as important light sources. They are finding some use for specialised lighting where efficiency and colour are not important and where high light output is not required, such as indicator, instrument and photographic dark room lighting.

Much interest now centres around the use of electroluminescence in light or image amplifiers. It has been shown[20] that in a specially constructed panel the intensity of a faint image, caused by u.v. radiation on the phosphor layer, may be amplified by the application of a d.c. field to the panel. In another arrangement[21] both conducting plates of the panel are transparent and interposed between one of the conducting surfaces and the phosphor resin layer is an opaque photoconducting layer of cadmium sulphide. In the dark the panel does not light up on applying an a.c. voltage since the cadmium sulphide layer is non-conducting. If a weak image is projected on to this it becomes conducting and the light pattern is reproduced in an amplified form on the electroluminescent surface.

A number of proposals have been made to utilise electroluminescence in television display systems, in extending the range of astronomical telescopes and in amplifying the X-ray images produced on fluoroscopic screens. Even for these applications, where the light flux requirements are relatively modest, much work will be necessary to obtain improved colour, higher amplification factors and reduced time constants of the effect.

Radio-active Krypton Lamps

Krypton occurs with xenon among the uranium fission gases generated during the operation of atomic piles. After purification the krypton contains about 3 per cent of the radio-active krypton isotope of mass number 85, having a half life of just under 11 years. This isotope emits mainly β rays, or electrons, with a maximum energy of about 0.7 MeV changing to a stable isotope of rubidium in the process. There is also a small amount of γ radiation, or short wave X-rays, given off.

The β radiation is capable of exciting cathodo-luminescence in sulphide phosphors of the type used in cathode ray tubes. There have been reports from the USA and elsewhere of fluorescent lamps operating on this principle without the aid of any external power supply. The United Kingdom Atomic Energy Authority has been working in this field* and has developed a number of fluorescent light sources of different designs using krypton 85[22]. Strictly speaking these sources are not discharge lamps but their use of luminescence justified some reference to them here.†

The krypton 85 lamp is exceedingly simple in construction, comprising a glass bulb coated on its inside surface with a suitable cathodo-luminescent phosphor (usually zinc sulphide or zinc cadmium sulphide). The bulb is evacuated and filled with the 3 per cent mixture of radio-active krypton 85 in stable krypton to a pressure of perhaps half to one atmosphere. Under excitation by the β emission from the active isotope, the phosphor glows with its characteristic colour—usually green or yellow to obtain the maximum luminosity. Very large bulbs are impractical because of the high cost of the isotope. There is, too, an appreciable loss of energy of the electrons in their passage through the gas, which amounts to perhaps 10 per cent after traversing about 6 cms in the gas at atmospheric pressure. For these and other reasons it seems unlikely that bulbs greater than about 10 cms in diameter will find much use.

In the type of lamp described, in which the light has to pass through the phosphor coating, the coating has to be thin enough to avoid serious loss of light by absorption.

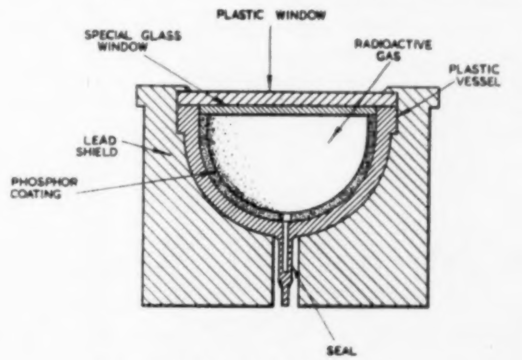


Fig. 14. Radio-active krypton lamp.

This means that full utilisation of the β ray energy is not achieved, some being lost in the glass bulb. The UKAEA has overcome this difficulty by making the bulb in the form of a hemisphere up to 3 or 4 cms in diameter, which may be of transparent plastic. The hemisphere is coated internally with a phosphor layer thick enough to utilise most of the electron energy and the light passes out through the base of the hemisphere, which is uncoated. The resultant lamp has 2 or 3 times the luminance of a comparable bulb source and possesses some directional properties. Fig. 14 shows a drawing of this cup-shaped source.

The luminance obtained from a green fluorescing phosphor is approximately 4 millilamberts using a filling pressure of about 300 mms of the 3 per cent mixture. Assuming no deterioration of the phosphor, the luminance will fall to half value in about 11 years. It is well known, however, that phosphors deteriorate under the action of cathode rays and it is not surprising that the best performance claimed indicates a decay of about twice the rate predicted from the half life.

* Patent App. No. 7964/58; further details may be obtained from the Patents Exploitation Officer, United Kingdom Atomic Energy Authority, 11 Charles II St., London, S.W.1.

† Another article dealing in greater detail with these lamps appears elsewhere in this issue.

The present cost of krypton 85 gas is approximately £15 per curie, but this is expected to fall to perhaps £5 per curie within a few years. This higher price corresponds to about £650 per litre of the 3 per cent mixture at NTP. Thus, the cost of the gas alone to fill a lamp of 50 ccs volume at 300 mms pressure would be of the order of £22.

Expressing all this in terms more usual in illuminating engineering, the total electron energy in the 50 ccs of the 3 per cent mixture at 300 mms pressure amounts to only 0.002 watt. The maximum efficiency likely to be achieved for green light produced in a cathode ray tube is probably not greater than 100 lm/w, so that the initial luminous output of the radio-active lamp in the example given is unlikely to be greater than 0.2 lumen of green light, or, say, 9,000 lumen hours in the 11 year period to half life of the krypton 85. Since the device cannot be switched off when not required, only a fraction of this output would be used in many situations. It seems clear that the use of sources of this type will be mainly for small indicating signs, clock faces, photographic dark room lighting and applications where the source may have to be left unattended for long periods, or where normal electrical supplies are not available.

It is not possible in the present article to deal authoritatively with the important question of health hazard in the use of radio-active krypton lamps. It is felt, however, that it will be possible to design and manufacture lamps which are entirely safe in normal operation.

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A Method of Measuring Cap Temperatures of General Purpose Tungsten Filament Lamps in Free Air

By J. N. BOWTELL,*
B.Sc., A.Inst.P.

Advances in design and manufacturing techniques of general purpose tungsten filament lamps have made possible in recent years substantial reductions in the size of these light sources. Bulb diameter and overall length have been reduced by as much as 10 per cent in certain wattage ratings and in others larger reductions are envisaged. This downward trend in size is helping to stabilise costs through savings in materials, higher processing speeds and economies in storage space.

Smaller bulb sizes imply, however, higher operating temperatures for the lamp caps and for the special cements used to fix them to the bulb. They may also lead to higher operating temperatures for holder and cable insulation and associated parts of the lighting fitting. Both cap cements and insulating materials are prone to deteriorate rapidly if the appropriate maximum safe operating temperatures are exceeded. Therefore, to take full advantage of reductions in lamp dimensions, much closer attention will need to be paid in future to lamp cap temperatures and the associated parts of the fitting.

The primary need is for a standardised procedure for measuring lamp cap temperatures in free air, that is to say, independently of the influence of holders and lighting fittings. Such a procedure will assist the lamp manufacturer to control cap temperature within specified limits. Also, in reducing lamp dimensions or in other design changes, it will enable the margin between the free air cap temperature and the maximum safe operating temperature of the cement to be accurately determined. This margin must be large enough to give adequate scope to the fittings designer, since operation of the lamp in a fitting frequently leads to an increase in lamp cap temperature.

Considerable experience has already been gained with the technique of lamp cap temperature measurement described in this article, and it is felt to be sufficiently accurate and consistent to constitute the basis of a standard procedure. This technique is intended primarily for measurement of lamps in the "cap-up" position, i.e. the position at which the cap is hottest, and consists essentially of supporting the lamp in a draught-free enclosure by means of its electrical

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supply leads, which are of specified dimensions, in order to provide repeatable heat loss conditions. The cap temperature is measured by a thermocouple in the usual way, again ensuring constant conditions of thermal loss at the point of measurement.

Apparatus

The equipment required is a draught-free enclosure, lamp support and terminal block, thermocouple and associated measuring equipment, voltmeter and wattmeter (or ammeter) for setting up the test lamp.

A double-walled enclosure made from perforated sheet is essential to provide draught-free conditions, whilst preventing progressive temperature rise within the enclosure. A suitable material for both chambers comprises 20 s.w.g. zinc sheet perforated with 72-0.085 mm diameter holes to the square inch. Some departure from this specification can be tolerated. The zinc sheet is formed into a cylindrical compartment 3 ft. in diameter and 3 ft. high encased in an outer compartment 3 ft. 6 in. in diameter and 3 ft. 6 in. high (see Fig. 1). Access is preferably arranged at the top. The shape of the enclosure is not critical, a cubic compartment of about the same overall dimensions and spacing between inner and outer walls is equally satisfactory. The ambient temperature within the enclosure may be measured by a mercury-in-glass thermometer, screened from the direct radiation of the lamp under test by a polished baffle. Figure 2 shows the arrangement for supporting the test lamp. A simple block serves as termination for the lamp supply leads and voltmeter leads. The lamp is suspended from this terminal block by two bare tinned copper wires 0.915 mm diameter (20 s.w.g.) and at least 100 mm long, soldered to the cap contact plates and clamped to the terminal block as shown.

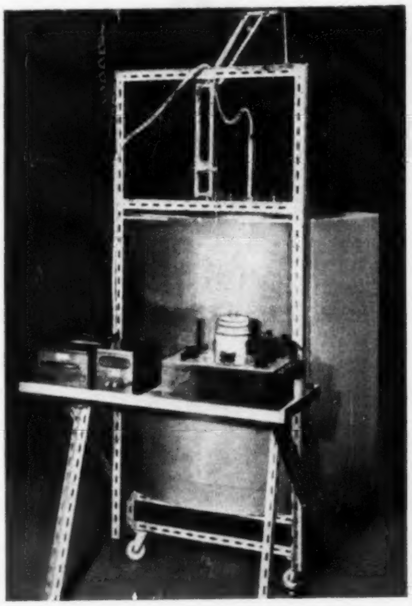

Fig. 1 (left) Apparatus used.

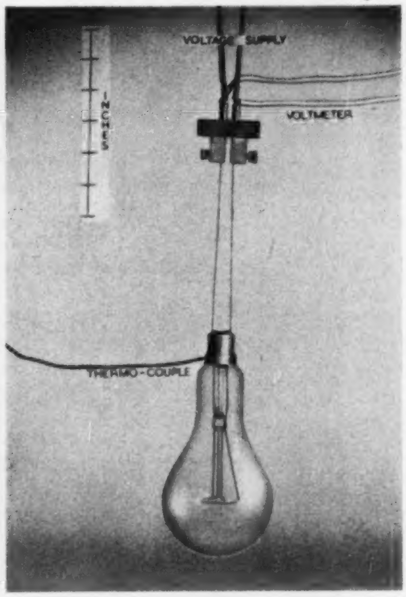

Fig. 2 (right) Arrangement for supporting test lamp.

The thermocouple is preferably made from 36 s.w.g. constantan and nickel-chrome wires, bright annealed in excess of 800°C. (These wires may be obtained from Henry Wiggin and Company Limited, under the trade names "Ferry" and "Brightray-C".) They should be paired together with glass silk insulation, the constantan being identified with a red thread. (Saxonian Electrical Wire Company Limited undertake this type of work.) The hot junction is formed by butt welding the two wires; a pair of 30 s.w.g. copper wires may be arc welded to the other ends of the thermocouple wires for connection to the measuring equipment. These two junctions, insulated from each other, are immersed together in melting ice and water to form the cold junction in the usual way. The thermal e.m.f. readings may be obtained by any suitable potentiometer technique capable of measuring to one micro-volt. To check the thermocouple calibration it is usually sufficient to make occasional measurements by hypsometer at the steam point.

The voltmeter used to set the lamp to the desired operating voltage should be accurate to $\pm \frac{1}{4}$ per cent. Wattage readings then show that the wattage of the lamp is not widely different from the marked value. In certain circumstances it may be required to set the lamp to a given wattage, when a wattmeter accurate to $\pm$ 1 per cent should be used.

Method of Test

The thermocouple hot junction is secured in intimate contact with the shell of the cap at a point on the periphery 3 mm from the cap mouth and as nearly as possible above the centre of the filament wreath. The hot junction is preferably soldered to the cap using the minimum amount of solder. (It may also be bound to the cap with fine wire or secured with a suitable adhesive such as a mixture of talc and waterglass, but the results obtained are somewhat less consistent.)

Measurement at the point described, which is in general the hottest, is usually sufficient for most work. If the mean temperature around the periphery of the cap is required, measurements may be made at additional points, spaced equally round the periphery. The cap shell must be at earth potential.

In making the temperature measurement, the lamp is suspended as close to the vertical as possible at the centre of the draught-free enclosure. It is set to operate at the required voltage (or wattage) for half-an-hour to allow the temperature to stabilise. Lamp cap temperature data is usually quoted in terms of temperature rise above the current ambient.

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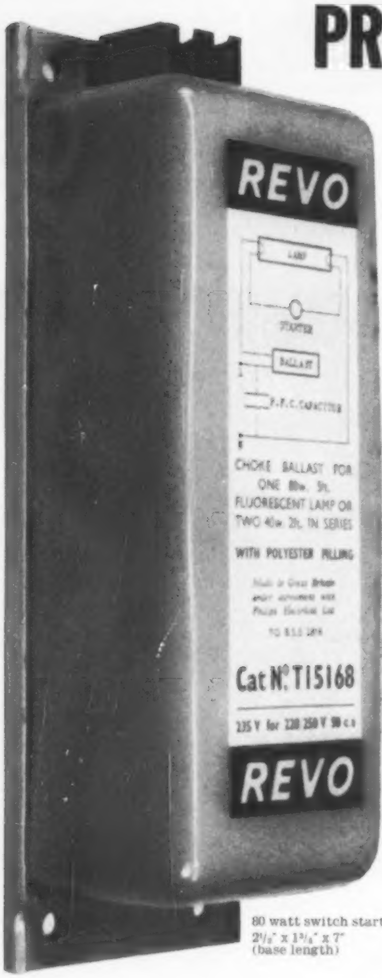

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The advent of artificial radio-isotopes has made available a large number of radioactive substances of which two gaseous isotopes, tritium and krypton 85, are suitable for use in light sources which need no outside power, the light being obtained from phosphors activated by beta particles emitted in the decay process of the radioactive gas. Sources of a few cubic centimetres in volume can be completely safe in operation and can be a negligible health hazard in the event of breakage.

By H. L. PRIVETT, B.Sc.*

and M. G. CLARKE, B.Sc.†

(1) Introduction

With radioactive isotopes becoming increasingly available in this country from the Atomic Energy Research Establishment at Harwell, it has been proposed that some of these would be suitable for employment in light sources. Such sources would be capable of running for numbers of years without attention (other than cleaning) and be completely independent of any external power supply. This article gives a brief review of the structure and behaviour of radioactive materials and describes the design and performance of some experimental sources of the type proposed, together with some possible applications.

(2) Radioactivity

It was not until the end of the nineteenth century that apparently inexhaustible sources of energy were discovered. In February, 1896, Henri Becquerel, who was working on phosphorescence, discovered the phenomenon of radioactivity.

Most of his initial experiments were conducted using uranium compounds and his discovery aroused great interest. The researches of Pierre and Marie Curie into uranium compounds having greater radioactivity than that which could be accounted for by the amount of uranium they contained, resulted in the discovery of other radioactive substances, including radium in 1898.

The work of Rutherford and others, on the emanations of these natural radioactive substances provided the knowledge that three types of radiation are given off. Rutherford found that two types of "rays" of particles were emitted, one called alpha particles, which were easily absorbed but which could cause intense ionisation, and another named beta particles of opposite charge which were more penetrating and caused less ionisation. A third highly penetrating radiation was found by Villard and named gamma radiation.

Alpha and beta particles being electrically charged could be deflected by a magnetic field but gamma radiation was unaffected, as shown in the diagram. (Fig. 1.)

It is known now that alpha (α) particles are in fact the nuclei of helium atoms and consist of two protons plus two neutrons and are, therefore, charged positively. Beta (β) particles are electrons and, therefore, much lighter than alpha particles and are negatively charged, whilst gamma (γ) rays are high frequency electromagnetic radiations having a wavelength (in general) shorter than X-rays.

As these various particles are emitted, the atomic structure of the radioactive element changes. It was soon found that the activity of a radioactive material does in fact decrease with time. This lessening of activity is known as the decay of the element and the time for a radioactive substance to lose 50 per cent of its activity is called its half life. The half life is a constant for a given radioactive substance and cannot be lengthened or shortened by heat. If equal numbers of atoms of two radioactive elements are considered, one element having a larger number of nuclear disintegrations per second (resulting in the emission of α, β or γ radiation) than the

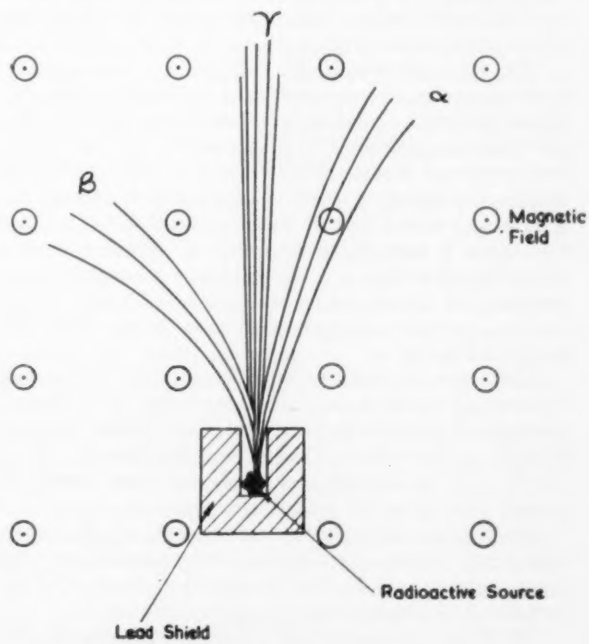

Fig. 1. Deflections of radiations from a radioactive source by a magnetic field.

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† Research Laboratory, BTH Co., Ltd.

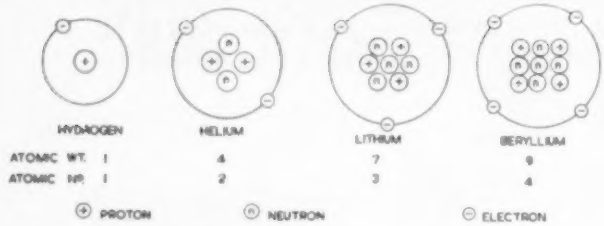

Fig. 2. Diagram of atomic constituents.

other it follows that its decay will be more rapid and, therefore, its half life less.

Radium is accepted as the standard for radioactive substances and has a half life of 1612 years. For 1 gramme of the element the number of nuclear disintegrations occurring per second is 3.7×10^{10}.

This rate, 3.7×10^{10} disintegrations per second is called a curie and the activity of a radioactive substance is expressed in curies. (This is rather a large unit and millicuries and microcuries are normally used, being 10^{-3} curies and 10^{-6} curies respectively.)

(3) Atomic Structure

With the discovery of radioactivity, the beginning of the century saw intense interest and experiment to determine atomic structure. It was originally supposed that the atoms of all elements consisted of a nucleus composed of a number of electrons and protons with further electrons revolving round it comparable to the sun and its planets on a greatly reduced scale. The nucleus was thought to consist of a number of protons equal to the atomic weight of the element considered, plus a number of electrons sufficient to give the nucleus a net charge equal to the atomic number and the number of electrons in orbit round the nucleus being sufficient to make the whole atom neutral in charge.

The existence of electrons in the nucleus was suggested by the emission of beta particles in radioactive decay but it was difficult to envisage a stable nucleus with positive and negative particles in close proximity. It was, therefore, suggested in the early 1920's that a neutral particle might exist having a mass closely equal to that of the proton, and such a particle was discovered in 1932. This was called a neutron, being a neutral combination of a proton with an electron. As previously mentioned alpha particles are helium nuclei and consist of two neutrons and two protons. Diagrams of some simple atoms are shown in Fig. 2.

Substances having the same atomic number possess the same chemical properties but they may have different numbers of neutrons in their nuclei and, therefore, have different atomic weights. These are called isotopes. Most of the classical chemical elements are now known to consist of mixtures of several isotopes.

In natural radioactivity, as mentioned previously, alpha and/or beta particles may be emitted during the decay process and this will change the structure of the nucleus, so various isotopes may be formed.

With the introduction of apparatus capable of producing fast moving particles such as neutrons, alpha particles and beta particles, it is now possible to bombard atomic nuclei and produce artificial isotopes. These artificial isotopes are nearly always radioactive and hence a large range of radioactive substances can be produced which do not occur naturally. Besides being produced by bombardment in the laboratory, artificial radioactive isotopes are produced as by-products of fission processes in nuclear reactors. There is today, therefore, a large range of radioactive substances available having differing characteristics.

Each radioactive isotope has its own characteristics, the type of particle it emits is fixed, as is also the average and maximum energies of the particle or particles.

(4) Isotopes Suitable for Light Sources

Hitherto radium and mesothorium compounds, mixed with fluorescent materials, have been used for low level light sources and are well known in their application to clock and instrument dials and their use in luminous paints. Unfortunately, attempts to increase the light output of fluorescent substances activated by radium or mesothorium have not been successful because the bombardment of the fluorescent substance by high energy alpha particles released in the process of radioactive decomposition has resulted in the fluorescent substance being rendered inefficient. Also for health reasons it is undesirable to have very large quantities of radium compounds in situations outside the control of knowledgeable persons.

The lighter radioisotopes, however, do not give out high energy alpha radiations in their decay processes and a number of them can be found which only give low energy beta radiation and in some cases gamma radiation.

The rate of decay of activity of such isotopes to half value ranges from fractions of an hour to years; and from amongst them one or two isotopes can be found whose half life is approximately 10 years[1]—which is a useful life for a manufactured article.

A gaseous isotope is attractive as it will disperse if accidentally released through breakage of the light source, and two gaseous isotopes—tritium and krypton 85—are possible choices for powering isotope light sources. Both of these isotopes are obtainable in this country from the Isotope Division of the Atomic Energy Research Establishment.

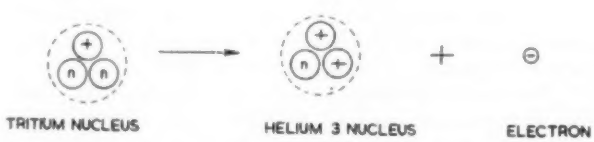

Fig. 3. Decay of tritium.

Tritium is an isotope of hydrogen having two neutrons in its nucleus. There is also another isotope known as deuterium or heavy hydrogen which has one neutron, but this isotope is non-radioactive. Tritium emits beta particles during the decay process and changes into helium 3 and has a half life of 12 years. (Fig. 3.)

It is produced by the irradiation of a lithium magnesium alloy in an atomic pile. The alloy in rod form is sealed in aluminium cans and the tritium is

removed by baking at 500°C in vacuo. Various purification processes are applied and the isotopes are absorbed in pyrophoric uranium from which tritium is eventually released by heating.

Krypton 85 has a nucleus consisting of 36 protons plus 49 neutrons and is produced in the fission of uranium. In addition to krypton 85 an isomer of 4.4 hours half life is produced which decays to the normal krypton 85 isotope with 10.6 years half life. In samples of krypton 85 obtained after purification there is little of the isomer left —it having decayed during the purification period. Eventually krypton 85 decays to a stable isotope, rubidium 85[2].

Tritium gives off only very low energy beta radiation whereas krypton 85 gives off beta radiation having higher energy and also some gamma radiation. Krypton further possesses the property, due to its being inert, of not combining with or contaminating other substances with which it comes in contact.

When krypton 85 or tritium are used the basic lamp source consists of a glass or plastic bulb coated on the inside with a fluorescent substance such as zinc sulphide and filled with the radioactive gas which causes the phosphor to fluoresce.

(5) Experimental Sources

(5.1) Construction

The first sources consisted of a glass bulb coated on the inside with phosphor and filled with radioactive gas. These suffered from two main disadvantages. Firstly, the light they produced was transmitted through the phosphor before being usefully employed, and this of necessity involved transmission losses, and the amount of light given out by the source was less than might have been obtained if phosphor transmission losses had been avoided. Secondly, the action of the beta rays from krypton 85 caused the glass bulb to become discoloured. A brownish " stain " gradually appeared below the surface of the glass and this reduced the light still further.

The lamps containing krypton 85 subsequently employed cerium glass to overcome this latter difficulty, as it has been found that such glass is not discoloured by beta radiation from krypton 85.

To avoid the transmission losses due to the phosphor, lamps are now made having a clear " window " to allow the light from the phosphor to escape with little loss.

The bulb is of hard glass and the phosphor, mixed with a suitable binder, is introduced through a short " neck " into the bulb and then allowed to drain. With the " window " technique, a thick coating which allows little light to be transmitted is desirable and several " coatings " may have to be repeated until a sufficiently thick layer of phosphor is obtained. The binder is allowed to dry and the window formed by carefully removing the phosphor by scraping. The bulb is then baked to dry off the binder, leaving the phosphor adhering to the bulb wall. A glass tube is then joined to the " neck " of the bulb to facilitate attaching to the exhaust and gas filling system, as shown in Fig. 4. The bulb is then filled with the required amount of radioactive gas and sealed off.

It will be appreciated that the size of the " window " determines the brightness of the source. If the " window "

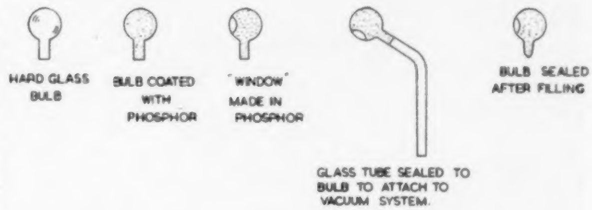

Fig. 4. Stages in making tritium source.

were infinitely small the surface of the phosphor would have maximum brightness, as the whole of the light generated would be reflected from side to side of the bulb in a similar manner to the reflection of light in an integrating photometric sphere. Over the area where the " window " occurs there is less reflection, and so the area opposite it does not receive as much light, and the inside of the bulb will be dimmer than if the " window " was not present. However, it will be appreciated that the total light output will depend on " window " area.

Neglecting brightness and considering only the amount of light emitted from the source, the ratio of " window " area to total bulb area for maximum light output will depend on the reflection coefficient of the phosphor coating. Calculation and experiment show, however, that the optimum " window " size does not vary greatly for different coefficients of reflection, and the " window " area can be taken as some 30 per cent of the bulb area for maximum light output[3].

With tritium activated sources no special shielding precautions are necessary as the beta radiation emitted is of very low energy and is completely absorbed by the glass wall of the bulb containing it. (Glass 0.01 mm thick is sufficient to absorb the radiation.)

Krypton 85 sources in general need shielding due to the gamma radiation they give out. Gamma radiation cannot be completely absorbed (as it is reduced exponentially in intensity when passing through an absorber) but can be reduced to a tolerable level such that a person receiving such an intensity continually would not be harmed. Whilst a krypton 85 source can be placed in a housing of sufficient dimensions such that it cannot be approached to within a distance at which its radiation exceeds the maximum permissible level, it is desirable that it should be surrounded by a lead shield to make handling safe before mounting, etc., as shown in Fig. 5. This design of source has been constructed by AERE, Harwell[4][5]. The shielding cannot, of course, be extended over the cerium glass " window " and low power krypton 85 sources should, therefore, be placed in housings of sufficient size that the gamma radiation in front of the window is reduced to a safe value. In practice a source of 80 millicuries had an intensity of 1½ times the permissible level directly on the cerium glass window, and below the maximum permissible level on the outer side of a glass lens some 3 in. away, so housings do not have to be of very large dimensions in practice.

In the lamps made in the laboratory the bulb containing tritium is clamped between two " Perspex " discs

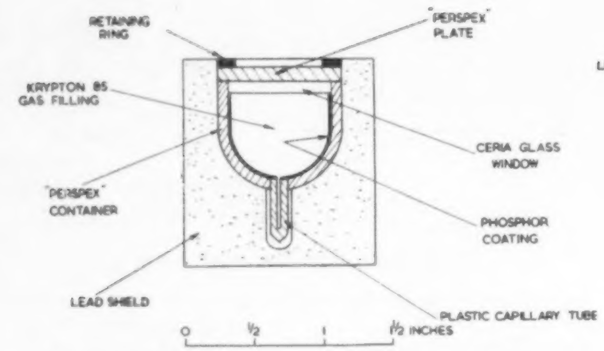

Fig. 5. Diagram showing section through a krypton 85 source.

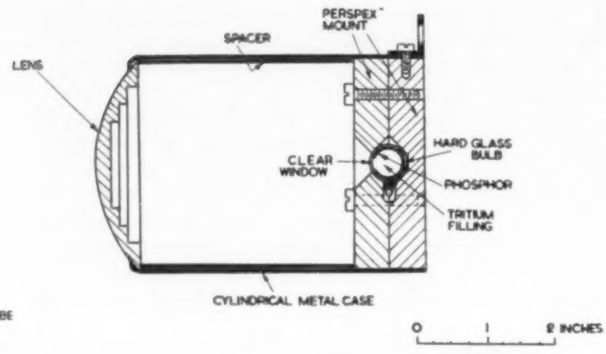

Fig. 6. Tritium radio-isotope lamp.

about half an inch thick, hollowed out to accommodate it. This " Perspex " mount is placed at one end of a cylindrical metal housing together with a cautionary notice to the effect that it contains radioactive gas, and sealed to prevent unauthorised opening. A glass lens is mounted at the other end of the housing and separated from the " Perspex " mount by a cylindrical " spacer ". A sectional view of the complete lamp is shown in Fig. 6.

(5.2) Characteristics

The characteristics of a typical source consisting of a bulb 1 cc in volume will now be considered. Without adopting special means to fill and seal at higher than atmospheric pressure, the maximum amount of gas that can be enclosed is therefore 1 cc at NTP.

(5.2.1) *Power*

Consider tritium first. This has an activity per cc at atmospheric pressure of 2.58 curies (1 curie $= 3.7 \times 10^{10}$ disintegrations per second). Each disintegration will result in the production of a beta particle, i.e. 9.55×10^{10} particles are produced per second. The maximum energy of these is 18.9 keV and the average 5.7 keV (1 keV $= 1.6 \times 10^{-16}$ joules). Therefore average power generated $= 2.58 \times 3.7 \times 10^{10} \times 5.7 \times 1.6 \times 10^{-16}$ watts $= 87$ microwatts.

In the case of krypton 85, this is usually obtained in the form of a mixture of 3 per cent krypton 85 and 97 per cent non-radioactive krypton. 1 cc pure krypton 85 has an activity of 1.67 curies at NTP so 1 cc of the mixture will have an activity of about 0.05 curies. Taking the average energy of the beta particles emitted as 230 keV,

Power generated $= 0.05 \times 3.7 \times 10^{10} \times 230 \times 1.6 \times 10^{-16}$ watts $= 68$ microwatts.

In each case the power generated is low. It will be appreciated that doubling the size of the bulb will increase the volume of gas contained by a factor of 2^3 and the surface area by 2^2 so the available power per unit area of phosphor will be increased by a factor 2. Great increases in loading cannot, therefore, be achieved by increasing the physical size of the source.

Compared with the beta radiation from most radioactive sources the energy of the particles emitted by tritium is very low, whilst that of those from krypton 85 is about an average value. Due to self-absorption the size of the gas container of a given shape cannot be increased with advantage beyond a certain limit. Beyond this limit the greater part of the beta particles will be absorbed before reaching the phosphor and play no part in light production.

(5.2.2.) *Maximum size*

The denser the substance through which the particles pass the greater the absorption. The range of particles is usually expressed in milligrams/cm². Dividing this figure by the density (milligrams/cm³) of the absorbing materials will give the range of the particles in centimetres.

Tritium at NTP has a density of 0.27 milligrams/cm³ and the beta particles have an average energy of 5.7 keV. Libby[5] gives the relationship between range and energy as $R = \frac{E^{5/3}}{150}$ where R is the range in mg/cm² and E is energy in keV.

For tritium this gives a range of 0.12 mg/cm² or 0.45 cm. It will be seen therefore that beta particles from tritium traversing a diameter of a 1 cm diameter spherical container at NTP will probably be stopped before reaching the other side, and it is therefore no advantage to make a purely spherical container much larger than 1 cm³ volume as the activity of the gas in the central region will not add much to the brightness of the phosphor on the walls of the sphere. For larger diameter containers, one can envisage other arrangements such as concentric spheres with the gas contained in the space between them[6].

Krypton 85 emits beta particles having a maximum energy of 695 keV. A rough rule is that the average energy is about ⅓ the maximum value, giving an average energy of approximately 230 keV[7].

Applying the formula used above in the case of tritium, the range of an average particle in krypton at NTP is about 16 cm. A spherical container of this radius would not be very practicable as the amount of gamma radiation emitted would require fairly heavy shielding to reduce it to a tolerable level, and hazards in the event of breakage would be considerable. The question of danger from the radioactive contents of the lamp sources will be dealt with later in the article.

The energy of the beta particles also determines what thickness of phosphor coating may be used in the lamp. Low energy beta particles from tritium will only penetrate the surface of the phosphor to a very small depth,

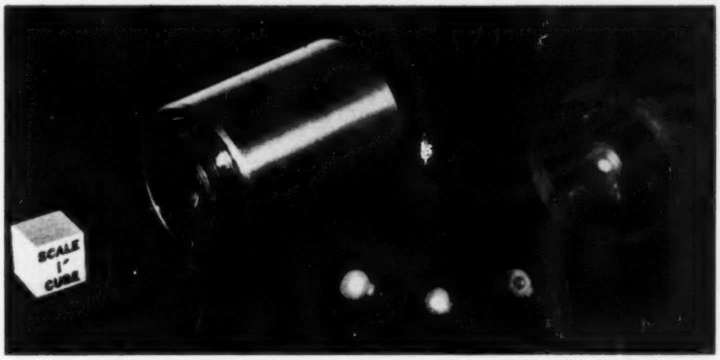

Fig. 7. Tritium powered isotope lamp showing component parts.

whereas the beta particles from krypton 85 will penetrate deeper. In this case, light may be emitted from portions of the phosphor well below the surface, and the size of the phosphor powder grains will have an effect on the amount of light emitted, as a certain proportion will be absorbed by the phosphor grains before reaching the surface and escaping.

(5.2.3) *Light output*

Due to the small amount of power available the light emitted by the sources is necessarily small. If all the power could be converted into green light at 5550 Å a 1 cc tritium lamp, as described, would only give approximately 0.06 lumen and one filled with a 3 per cent krypton 85 mixture, 0.05 lumen. These figures represent a theoretical maximum and are not achieved in practice. If pure krypton 85 was used a 1 cc lamp with a theoretical output of 1.5 lumens is indicated. Present troubles with the deterioration of phosphors and binders under high loadings of gamma and beta radiation make this more difficult than originally supposed.

Experimental lamps made in the laboratory give an output of about 0.0045 lumens representing an efficiency of just over 40 lumens/watt. This figure does not represent the maximum possible as these lamps did not have a window area designed to give maximum light output.

(5.2.4) *Brightness*

In spite of the small available energy, a 1 cc source will give brightnesses of a practical value. The brightness of such a source will depend upon the amount of radioactive gas it contains and also the type of phosphor used. Zinc sulphide phosphors are normally used and can be made in a range of colours, green and blue having the highest luminous efficiency.

Blue and green sources constructed in the laboratory and filled by AERE, Harwell, with 2.2 curies of tritium give approximately 1.8 ft-lamberts. A source constructed at Harwell, of rather larger volume containing 80 millicuries of krypton 85 and coated with a yellow phosphor gave about 2 ft-lamberts. However, the 3 in. diameter lens of the present lamps is visible in darkness at about $\frac{1}{4}$ mile distance.

Table 1 shows the brightness of typical isotope sources compared with that of conventional sources.

Table 1

Light source	*Brightness ft.-L*
Tungsten filament	2.5×10^6
Bright spot on pearl lamp	2.4×10^4
Sodium lamp	2.4×10^4
80W MCF/U lamp	2.5×10^3
Illuminated road signs in lighted streets	15
Electroluminescent panel on 500 cycle supply	10
Electroluminescent panel on 50 cycle supply	2
Isotope lamp (yellow) filled with 80 millicuries krypton 85	2
Isotope lamp (green) filled with 2.2 curies tritium	1.8
White object in bright moonlight	0.1
Radioactive paint	0.02
Dark room lamps	
Orange (gas light)	10
Deep orange (bromide)	1.5
Red (orthochromatic)	0.25
Green (panchromatic)	0.025
Zinc sulphide screen excited by UV 125W black lamp at 3 ft.	5

(6) Applications

It can be seen from Table 1 that these isotope sources are not lamps in the accepted sense for providing illumination; but they have a field of usefulness as indicators. There is clearly more likelihood of their application where the provision of other forms of power is difficult or costly, and where maintenance is a problem. One such case is in the transport industry and tests are being made on some American railroads using krypton powered sources. If the present brightness figures could be eventually increased by a factor of, say, 10, further uses could be found. These include markers for obstacles or equipment that might be collided with in darkness, such as aircraft ground equipment, or as safety markers in mines. Markings for entrances and emergency exits could employ isotope sources and they could also be used for marking aircraft loading ramps and for police and fire call boxes. At sea, they have been suggested for emergency channel markers and for short range signalling equipment on life rafts[8].

The sources could be used with safety in situations where fire risks from conventional electrical sources are prohibitive.

(7) Health Hazards

(7.1) Normal Operation

In the section on the construction of gas isotope sources, it has been pointed out that the energy of the

beta particles emitted from tritium is so low that no shielding is necessary as the beta radiation is absorbed by the glass wall of the containing bulb. No shielding problems arise, therefore.

In the case of krypton 85 the main shielding problems arise from the fact that it is necessary to reduce the gamma radiation to a tolerable level. A lead shield about ½ in. thick will provide sufficient shielding for a 1 curie source to reduce the radiation to a tolerable level 20 cm away. For a source 16 cm radius (the limiting value from a self-absorption aspect) the activity for a 3 per cent krypton 85 mixture filling at NTP would be 860 curies so the shielding would have to be increased by a factor of $\log_e 860$ and would therefore be about 3½ in. thick for roughly the same safe level. A source of this size would run at a power of 1.2 watts. Some sort of labyrinth and a system of mirrors or prisms would have to be employed to allow the light generated to escape and still shield the gamma radiation. Such a source would be extremely costly and rather impracticable.

It will be seen that there is little difficulty in making gaseous isotope sources completely safe whilst they remain undamaged. Any health hazards that may arise will occur if the source becomes broken and the contents escape.

Hard glass bulbs of a few cubic centimetres volume are quite robust if they are annealed, and even the more complex type of bulb with a cerium glass window can be made very strong. There need be no risk of explosion or implosion if the difference between the pressures inside and outside the bulb is kept very small. If only a small amount of radioactive gas is needed for a particular size of source, it can be diluted with a non-radioactive gas rather than filling the bulb at a reduced pressure.

(7.2) Breakage conditions

If by mischance the bulb containing the radioactive gas is broken the gaseous contents will disperse automatically into the atmosphere and be diluted, instead of laying about unshielded as would be the case if they were in a liquid or solid form. With krypton 85, good ventilation for a sufficient length of time will ensure the dispersion of almost any quantity down to a safe level.

Tritium being a hydrogen isotope will combine with other substances and it has been found that there is a large difference in the amount of tritium absorbed by the body depending upon its chemical form when inhaled. If the tritium is in its elemental form, the majority of it is exhaled and not absorbed by body tissues, but if it is oxidised (e.g. by passing through a flame) to form tritiated water, the greater part is absorbed. The biological half-life is, however, fairly short, being about 19 days, i.e. after this period half the tritium initially absorbed by the body will have been excreted in one form or another.

During its stay in the body the absence of gamma radiation renders tritium less toxic than many other radioactive substances and as the beta particles emitted have such a low energy they cannot penetrate deeply into the body tissues.

When tritium occurs in the form of tritiated water the tolerance level is low and the maximum permissible level is about 0.25 millicurie for a 10-ft.-cube room, according to the Recommendations of the International Commission on Radiological Protection. However, it is estimated that about 15 curies of tritium in its elemental form could be dispersed in a 10-ft -cube room without exceeding the tolerance level. In well ventilated situations greater activities could be released without ill effects[10]. It will be appreciated, however, that this is for continuous safe working, i.e. 40 hours per week and larger doses could probably be tolerated for shorter periods.

(8) Future Possibilities

The use of present gaseous isotope sources is limited due to their small power output and the cost of the radioactive contents. With increased demand and production of radioactive isotopes this latter limitation may be reduced. Also enriched krypton 85 mixtures, when available, will enable higher loading of the phosphor to be achieved and techniques may be adopted whereby bulbs can be filled with pressures of gas greater than atmospheric.

The use of tritium in gaseous compounds where it could replace hydrogen in such gases as hydrogen sulphide (giving olfactory warning in the event of breakage) may be desirable.

The results of experiments on the present sources constructed may give rise to better phosphors and binders, and the depreciation of light output due to the reduction in efficiency in converting beta radiation to light may be reduced.

At the present time these gaseous isotope sources already give brightnesses very much in excess of those obtained from radioactive paints, etc., and it is considered that they may prove of use in situations where electrical or flame sources are unsuitable.

Acknowledgements

We wish to acknowledge the help and advice given by colleagues in the BTH Research Laboratory and the A.E.I. Lamp and Lighting Co. Ltd., and also by Dr. E. J. Wilson of the Isotope Division, AERE, Harwell.

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We are informed by the Pergamon Institute, who have prepared a translation of the new Soviet standards of lighting, that an extensive fire at their premises in Fitzroy Square has destroyed their copies of the translation as well as applications they had received from a number of sources for a copy of the translation. The Pergamon Institute will be grateful if applicants will repeat their requirements and will understand that some delay in meeting these will be unavoidable in the circumstances.

NEW PRODUCTS

VHO reflector tube

Atlas Lighting Ltd. have introduced a 5 ft. 150-watt Very High Output reflector fluorescent tube (VHO/R). The tube has bi-pin caps and incorporates an internal semi-translucent reflector surface to concentrate the light into a single plane. The new tube is said to be suitable for applications where extra lighting intensity is required for a comparatively limited period. One of the experimental applications of of the VHO/R tube has been in the lighting for *Son et Lumiere* spectacles at Woburn Abbey, Cardiff Castle and Greenwich. The price of the tube is 35s. list.

Universal start fluorescent tubes

In place of the three alternative finishes previously available (i.e., plain for switch start circuits, external metal stripe or siliconed for instant start circuits), every "Osram" 5 ft. 80-watt tube will in future be supplied as standard, fitted with an external conducting stripe. These new Universal Start 5 ft. tubes will be sold at the same list price (13s.) as that previously charged for switch start tubes. The development, which enables the 5 ft. tube to be used with switch and switchless start start circuits, will prove of great benefit to the trade in helping to reduce the range of tube stocks, simplifying the ordering procedure and enabling the user to reduce his intitial installation and maintenance costs by the cancellation of the extra charge made for the metal stripe and for the siliconing process. The introduction of the universal start tube has been made possible by the development of a new, low-cost processs for the application of a conducting stripe to the exterior surface of the tube. The GEC is planning to extend the universal start to the complete range of tubes.

The A.E.I. Lamp & Lighting Co. Ltd. has also announced a Universal lamp to replace different lamps for switch and instant start circuits but will retain a metal tape stripe lamp for applications requiring flameproof and dustproof fittings, cornice lighting and places where low temperature and low voltage are experienced.

Fluorescent lamp fittings

Atlas Lighting Ltd. have added three new fittings to their "Atlantic" fluorescent range.

First of the new fittings (series 1B) has an attractive opal diamond-textured acrylic plastic diffuser with interchangeable clip-on end panels available in six colours—red, yellow, blue, pastel green, black and white. 8 ft., 5 ft., 4 ft. and 2 ft. sizes are available, the 8 ft. version having a plain opal diffuser. Metalwork is stove-enamelled white with matt black chassis end plates. The second fitting (series 1C) is a twin tube 5 ft. fitting with an acrylic plastic diffuser and canopy moulded in one piece, with a ribbed underside to give a pleasing contrast with the other surfaces. The third fitting (1E series) has been designed to meet the demand for a twin tube fitting with a low priced louvred diffuser attachment. The diffuser is made up of standard 5-inch "Twinluve" sections in pearl finished polystyrene, clamped together with a white enamelled rod, and white metal end plates. The complete diffuser is re-assembled and easily removed from the chassis by unscrewing knurled studs at the end of the fitting. This fitting is available for 8 ft., 5 ft., 4 ft. and 2 ft. lamps.

Two new features which will now be standard on all Atlas "Atlantic" fittings are a special universal suspension channel with sliding stirrups adjustable to any desired fixing centres and a modified diffuser support tray which simplifies installation and maintenance.

Atlas also announce four new series extending their "Popular" range to industrial reflector and commercial diffuser fittings together with a twin tube version of the original "Popular Pack." They have been designed to

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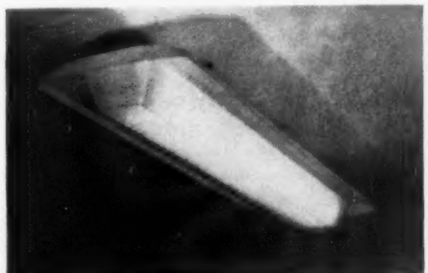
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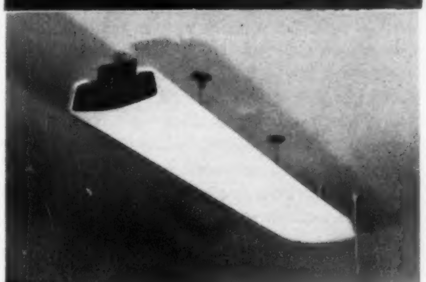
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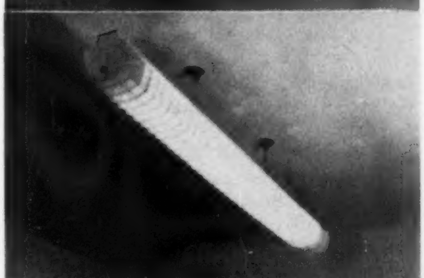
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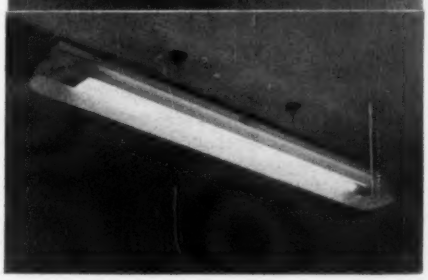


Some of the new ranges of Atlas fittings:
1. "Atlantic" twin tube fitting.
2. "Atlantic" twin tube commercial fitting.
3. "Popular" commercial fitting.
4. "Popular" translucent trough.

One of the Ekco " Essex " louvred fittings.

meet the needs of industrial and commercial users who require good looking, good quality fittings, efficient in performance, reliable in operation, yet low in price.

The " Popular " (series KB) are available in 5 ft. single (£7 12s. 0d.) and twin (£11 18s. 0d.) tube versions and are fitted with an open-ended metal reflector, slotted to give a degree of upward lighting.

The (series KA) is available in single (£11 18s. 11d.) and twin (£16 9s. 4d.) tube 5 ft. 80-watt sizes. An attractive enclosed reeded opal " Diakon " diffuser fits easily on to the basic chassis. The diffuser is open-ended and slides over metal end plates which are finished in grey whilst all other metalwork is stove enamelled white.

The (series KT) is also available in single (£10 1s. 8d.) and twin (£15 3s. 4d.) tube 5 ft. 80-watt sizes. These fittings have a single piece translucent opal " Perspex " trough which gives a good degree of upward lighting for industrial and commercial interiors.

The (series KO) is available for single and twin tube versions in both 5 ft. 80-watt and 4 ft. 40-watt sizes. " Twinluve " pearl finished polystyrene diffuser sections are fitted to the basic batten chassis to provide an attractive fitting for all commercial lighting applications. The 4 ft. size complies with Ministry of Education requirements for school lighting. The single 4 ft. fitting costs £10 15s. 4d. and the twin lamp 5 ft. fitting £17 3s. 10d.

All prices quoted above are tax paid and include complete fitting, control gear and Atlas " white " tubes. They are tapped for all voltages from 200/250 and pre-packed ready for immediate sale. All fittings except the twin tube pack are equipped with bi-pin lampholders.

Ekco-Ensign Electric Ltd. have also introduced some new ranges of fluorescent fittings.

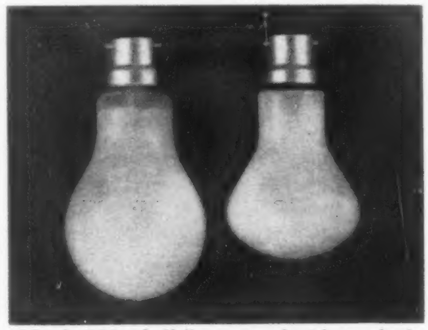
Their " Essex " range has been designed with a view to reducing costs of installation, maintenance and storage and covers over 200 different fittings based on one universal section spine. The range at present is for 5 ft. and 4 ft. tubes and will be extended to cover 8 ft. tubes in the near future.

The spine can be attached to chain or conduit suspension or fixed direct on to the ceiling. The hinged control gear tray is then hooked to one end of the spine and hangs vertically leaving both hands free to make connections after which it is swung up into position. The lampholders, reflectors or coverplates and tubes are then fitted. A variety of reflectors in metal, " perspex " and p.v.c. are available. Seven types of " perspex " diffuser are also available, four closed and three louvred versions. These hook onto one edge of the coverplate and are slipped over the other edge. Endplates for diffusers are of metal in any of six colours.

The second Ekco range is known as the " Economy " range. It covers five types of fitting in 5 ft. and 4 ft. sizes, single and twin tube. The simplified line of this range enables it to be mass produced at a lower price and is intended for use in installations where capital cost is of primary importance.

Lamp bulb

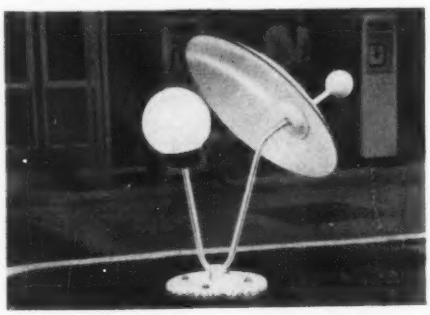
The A.E.I. Lamp and Lighting Co. Ltd. has introduced a new compact 100-watt " Silverlight " tungsten lamp smaller than the usual household lamp and of an entirely new shape. Known as the " Netabulb " it has the same light output and efficiency. Because the dimensions of the "Netabulb" are smaller than those of a standard 100-watt GLS lamp, it is suitable for use in many modern light fittings. The bulb has an internal white coating which diffuses the light with the minimum of absorption and a coiled-coil filament which gives considerably more light than a single coil of the same rating. Designed for use in the home, offices, hotels and as a general replacement where the present 100-watt lamp is used, the " Netabulb " is available in a range of standard voltages and will shortly be obtainable in several other wattages.



Mazda " Netabulb " compared with standard 100-watt lamp.

Service station bollard

A new bollard of contemporary design has been developed by Wades (Halifax) Ltd., Fenton Road, King Cross, Halifax. The unit is designed for illuminating roadway entrances from low level positions. Light is reflected downwards and forwards from a 10-in.-diameter totally enclosed water-tight glass sphere suitable for 100-watt lamp. Steel metal work is rustproofed and an aluminium reflector and seamless ball are stove enamelled white with any standard contrasting colour on the back of the reflector. Special fixing base plates can be made to order.



Wades' service station bollard.

Ballast unit

A new ballast unit for fluorescent lighting is announced by the Midland Coil Winding Co. Ltd., of 4, Lancaster Street, Birmingham. A bitumen-free choke and exposed capacitors and transformer, or switch, permit easy removal and replacement merely by removing the base fixing screws. The tray is fitted with a pressed steel cover which will slide, or spring on where installation is required in confined spaces.

Lighting Abstracts

LAMPS AND FITTINGS

628.92

621. Control of daylighting with reflecting jalousies.

T. CARSON, *Illum. Engng*, **53**, 337-340 (*June*, 1958).

As an alternative to venetian blinds, curtains, horizontal or vertical louvres for controlling the interior daylighting of a school classroom, a system of adjustable horizontal glass louvres has been devised. Each louvre comprises a 4-inch width of 1/32-inch patterned glass, the patterned side being sprayed with metallic aluminium. Photometric measurements demonstrate the effectiveness of the louvre system in redistributing daylight and consequently reducing brightness contrasts. When the louvres are closed the room interior is sufficiently dim to use visual aid equipment. P. P.

628.93

622. Effect of temperature on light output from open and enclosed fluorescent fittings.

C. LOEF, *Lichttechnik*, **10**, 259-261 (*May*, 1958). *In German.*

Owing to the rise of temperature inside an enclosed fitting, the light output from the lamp is reduced. This effect is especially marked in the case of fittings with several lamps. The author gives a number of experimental curves showing, for various types of fittings, the extent of the reduction at different ambient temperatures. He concludes that the effect broadly balances the smaller reduction of light due to dust collection which is experienced with enclosed fittings. J. W. T. W.

628.92

623. Daylight illumination and brightness with minute louvres.

W. B. EWING and R. L. BIESELE, Jr., *Illum. Engng*, **53**, 331-336 (*June*, 1958).

Minute louvred materials originally developed to minimise solar heat gain through windows have, in use, been found to have advantages as daylight control devices. Typical materials have inclined slats only 1/20th-inch wide spaced at 17-23 per inch, and are made from thin ribbons of bronze chemically darkened or by slitting small segments of sheet aluminium. The materials admit light directly only from that portion of the sky near the horizon and hence form an effective sun shield. They also act as a shield against sky glare, allow a free flow of natural ventilation and, by virtue of the small size of their slats, do not intrude on the view through the window. P. P.

624. Colour of "white" fluorescent lamps. 621.327.534.15

R. LOCHINGER and M. J. O. STRUTT, *Bull. Assoc. Suisse Elect.*, **49**, 523-529 (*June* 7, 1958). *In German.*

Reports the results of an extensive series of spectral distribution measurements on 5 different types of white fluorescent lamps obtained from 6 different manufacturers. The uniformity among lamps with the same name is much greater than in a similar investigation carried out in 1951. A number of spectral distribution curves are reproduced and the chromaticity co-ordinates are given. The most uniform group is that described as "reinweiss" or "coolwhite." J. W. T. W.

625. Sodium vapour lamps and vibrations. 621.327.5

S. A. BACHE, *Ljuskultur*, **30**, 61-62 (*April-June*, 1958). *In Norwegian.*

Trouble was experienced with short lives of sodium lamps installed on a bridge, and this was traced to vibration, the lamps breaking at the joint between the lamp itself and the outer. The problem was finally solved by an asbestos cushion. A diagram is given of the solution which, however, although giving a marked improvement, has not yet been in operation long enough to outlast the normal life of the lamp. R. G. H.

LIGHTING

626. Office buildings in Sweden. 628.973

L. HOLM *et alia*. *Byggmästaren*, **36**, 105-132 (No. A5, 1957). *In Swedish.*

A symposium on recent office buildings in various parts of Sweden. Holm (p. 106) draws attention to the practical significance of Hesselgren's theories of lighting and colour. The new building of SIF (Svenska Industritjänstemanna Forbundet) includes a roof restaurant with a "Danish-school" type stepped roof system of fenestration (p. 118). R. G. H.

627. Planning street lighting installations. 628.971.6

E. K. MULLER, *Lichttechnik*, **10**, 316-319 (*June*, 1958). *In German.*

In an earlier paper (Abs. 426, April, 1957) the author described a method for finding the average illumination on a street lighted by means of linear sources mounted lengthwise over the centre-line of the street. In the present paper a similar method is used for sources mounted at right angles to the line of the street and either horizontal or tilted upwards. The same assumption is made as before, *viz.*, that the polar curve in any plane through the axis of the fitting is a circle, and tables are given by means of which the illumination curve for any line parallel to the street can be found from the principal polar curve for the source. J. W. T. W.

628.97

628. Installation of stage lighting of the Opera Louis XV at the Château de Versailles.

G. LEBLANC, *Rev. Gen. Elect.*, **67**, 305-325 (*June*, 1958). *In French.*

The installation of stage lighting at the Opera at Versailles is described in detail. Control is derived partly from the system already installed for the control of the exterior lighting for the Sound and Light Spectacle, which provides 72 circuits for the Opera, operated remotely. In addition an electronic control board has been provided, using thyratrons and saturable reactors. In addition to the conventional sources, some fluorescent lamps are used as cyclorama lights, the cathodes being permanently independently heated to permit dimming. A special xenon spotlight is also provided in which a xenon lamp is arranged in a vertical projection system incorporating conventional masking arrangements and also three colour filters giving a "chromoselector" type of colour control. A mirror at the top of the apparatus is used for following. J. M. W.

I.E.S. ACTIVITIES

Presidential Address

At the opening meeting of the 1958/59 session of The Illuminating Engineering Society held at the Royal Institution on October 14th, Mr. C. C. Smith was inducted as President of the Society and delivered his Presidential Address entitled " Light and Life."

Mr. Smith said that without artificial lighting the whole pattern of life would be changed. The hours of natural light were insufficient for modern needs and consequently the science or art of lighting pervades every aspect of everyday life.

Lighting plays an important part in the sustainment of life. To preserve a reasonably high standard of living it is essential that an extremely high rate of production be maintained and here lighting improvements have been of inestimable value, directly, by speeding and improving works processes and indirectly, by decreasing accidents and creating a pleasant environment for work. Better lighting has brought about increased production, and lighting in factories of all kinds has contributed greatly to the nation's well-being.

In the preservation of life, lighting is doing much towards the prevention of accidents on the road. Latest figures indicate that the provision of good modern street lighting reduces the figure of injury accidents in darkness by an average of 30 per cent.

Lighting of a very high quality has rendered indisputable and invaluable service to the medical profession. Lighting improvements have helped to preserve life by being responsible in no small way for the tremendous steps made in the prevention of illness. Lighting techniques and light sources have placed in the hands of the specialist and surgeon tremendous assistance in their fight against illness and disease. Light enables them to perform the most delicate operations, light from sources of extremely small dimensions permits them to see the origin and development of disease actually inside the body and light can be used to alleviate pain or fight the disease at its source.

In establishing and emphasising how important and vital a place artificial lighting occupies in our lives today, it is not unreasonable to assume, from that fact, that The Illuminating Engineering Society itself holds a relatively similar position. The Society is nearing its Golden Jubilee—50 years indirectly in the service of the public, during which time it has quietly and unobtrusively, but nevertheless effectively, contributed great service to the community. The future of the Society lies in its individual members, in their willingness to sacrifice time and energy in the desire and the will to acquire, share and disseminate knowledge. Encouragement must be given and facilities provided for the many young men who must be attracted to the profession.

Finally, Mr. Smith appealed for co-operation and mutual understanding between kindred societies and organisations in order that the tendencies to confine activities within the limits of specialised subjects are halted and the artificial barriers to wider knowledge and understanding are removed.

The vote of thanks to Mr. Smith for his address was proposed by Mr. J. M. Waldram and seconded by Mr. F. J. Burns.

Birmingham Centre

On September 26th the Birmingham Centre opened its 1958/59 programme with an address by the new chairman, Mr. L. E. Gibbs, entitled " Modern Lighting and Production ".

Mr. Gibbs dealt with the development of modern trends in lighting over the last thirty years. Drawing on personal experience Mr. Gibbs said that for years it has been an ambition to give more and more light, with better diffusion, with lower brightness, and, with the co-operation of architects, built in or concealed lighting. Much of this, said Mr. Gibbs, has now been achieved.

The lighting engineer of the future must have a comprehensive knowledge of colour, industrial psychology, architecture, sales and publicity. He should be familiar with the different effects of colour and the correct use of light and shade.

In conclusion Mr. Gibbs insisted that the lighting industry must move with the times, and in common with other industries must design its products not only for efficiency and appearance, but also for mass production and so cover the every need of so many industrial and commercial lighting installations.

GOLDEN JUBILEE DINNER

Applications for tickets for the above dinner to be held at the Criterion Restaurant, Piccadilly Circus, London, W.1, on Tuesday, February 9th, should be sent to the IES Secretary without delay.

Leicester Centre

The Leicester Centre held its opening meeting for the new session on Monday, September 29th, when the new chairman, Mr. A. E. Bird, was inducted. The retiring chairman, Mr. A. Y. Johnson, in handing over made a brief reference to Mr. Bird's untiring work as secretary, a position he had held for the past four years, and wished him every success in his new office. Mr. Bird suitably replied and then proceeded to deliver the chairman's address.

The address was in two parts, and Mr. Bird first spoke of the Society, its aims and objects, and the valuable contribution it had made to the community in providing a better understanding in the use of light. Since the formation of The Illuminating Engineering Society tremendous advancements had been made in the science of lighting and the future may produce more new and exciting light sources and methods of application.

In the second part of his address Mr. Bird dealt with Home Lighting and illustrated his talk by showing coloured slides of the lighting he had in his new house. He illustrated quite clearly that with a little intelligent thought, lighting in the home can be scientifically planned and decorative, thus providing a basis for better living.

A vote of thanks to Mr. Bird was proposed by Dr. A. B. Whitworth.

At the meeting in Leicester on October 27th Mr. J. R. Just, Chief Illuminating Engineer of the Architects' Department of Boots Pure Drug Co. Ltd., gave a lecture on Shop Lighting in which he illustrated with some excellent coloured slides the tremendous contribution modern and well-designed lighting made to a store. As well as producing light conditions to encourage the selling of merchandise, consideration had to be given to making the store an interesting and an attractive area for customers. The compara-

tively new 8 ft. fluorescent lamp was a very satisfactory and practical light source for this purpose. Maintenance was a very important factor in store lighting and Mr. Just said that he considered bulk replacement of lamps would go a long way in easing this problem.

The discussion was opened by Mr. A. H. Nash and a number of members and visitors took part.

Manchester Centre

At the first meeting of the Manchester Centre in the new session held on October 2nd a lecture on "Lighting and Interior Decoration" was given by Sir Gordon Russell, Director of the Council of Industrial Design. The meeting was held at the Regional College of Art in Manchester and the audience of 250 included many architects, interior decorators and students. The following are some extracts from Sir Gordon's remarks :—

One of the chief differences between today and all previous ages, said Sir Gordon, is that we have reached a stage where practically everything we use is made by machine. To make things efficiently by machine it is essential to subdivide processes. This applies not only in manufacturing but has meant also that retailing has become entirely divorced.

In every walk of life we find specialists who know little of developments outside their own field. Even the architect tends to specialise in schools, hospitals, factories, office blocks—it is the only way he can get to know enough of the highly technical problems involved. We must remember that lighting itself is only one aspect of architecture—a very important aspect without which we should not be able to look at any interiors after sundown—but still only one aspect. To appreciate this in reasonable perspective it is essential to look at architectural developments which are happening under our noses.

Will the technicians have it all their own way and will building become a trade ruled entirely by accountants? Or will that much maligned person, the artist, find a way of coping with an involved situation—will the artist, as architect, be able to invest these strange new forms with a poetry of their own or will they be dedicated to an ever growing extent to ineffective efficiency? Our buildings must be suitable for their purposes but this surely is a very limited aim. They should inspire our daily life. If they do not do so shall we have become so impregnated with ugliness that we do not notice what has happened? If architecture goes down the wrong road, there is little that one small facet of it can do about it except rebel. That determined minorities have often proved the tail which wagged the dog should be some consolation.

The effect of the machine is particularly noticeable in lighting fittings. The wonderful hand-chasing of earlier times, including the Victorian gas chandelier, which one cannot help admiring even when the design seems inappropriate and ugly, has given way to an assemblage of tubes and pressings. Many of these are neat, efficient and even quite pleasant in shape. Their price often seems fairly high yet we tend to have several in a room instead of the single central light so common in many Victorian rooms and this is all to the good. Yet when we feel that certain positions call for fittings of a somewhat more decorative character there is little available which is entirely suitable for electric light and yet has a similar quality to the brass chandeliers of the 17th century or the cut glass ones of the 18th without being in any way imitations of them. Of course, in both these cases the polished material was an admirable reflector for the flicker of the candles which gave them a liveliness and gaiety we miss in electric light.

Yet electric light has so many good qualities—cleanliness, ease of manipulation from a distance, far less heat generation than any previous form of lighting—that it seems odd that it has not stimulated our designers to invent decorative forms of our own day. Perhaps too many of them have accepted the statement made fifty years ago by Adolf Loos, the Austrian architect, that the lower the standard of a people the more lavish are their ornaments. Though there is no need for frills on everything, there are occasions when they would be pleasant, although it is undeniably true that machine-made ornament usually has a dull flat look.

Then there is a matter of shadows. It seems that the lighting engineer is not satisfied until he has managed to achieve a complete uniformity of intensity in his effects. But the artist in lighting paints with shadows, placing his lighting just where it is needed. Fortunately this is usually a good deal cheaper, otherwise the mysterious beauty of many a great Gothic church might be lost to us.

Sir Gordon said that he had stressed these unusual aspects of lighting because he thought it important that everyone connected with its more humdrum day-to-day problems should make a point of looking at them when opportunity offers.

Lighting must also take account of its background. It is essential for all those concerned with the lighting of buildings, both inside and out, to have an interest in, and therefore some knowledge of, today's architecture. It is necessary to be able to discriminate between its good, bad and indifferent manifestations. For whether or not we like it, an architecture of our own day is at last emerging after the century-old battle of the styles. This modern architecture is based on the fact that factory made components and prefabrication of units is bound to replace work on the site. Today it is much less costly to transport factory-made goods for long distances than to use local materials by hand on the site. This naturally means that there will be rather less elasticity in planning a house than there has been in the past. Therefore it ought, at least in theory, to be easier to work out the most convenient places for lights. The snag, of course, is that people have widely differing requirements in the same kind of room. But at least it should be possible to meet some of them.

The public is showing many signs of appreciation of good design. Since the Duke of Edinburgh opened the Design Centre in Haymarket two and a half years ago nearly two million people have visited it, and there is no sign of a drop in the daily average of over 2,000. Here a selection of well-designed goods is shown so it is idle to claim that the public is not interested. The fact is that the retailer is often unaware of the rapid growth of interest and in many towns makes no effort to cater for it. We have now reached a point where social service and commercial success are not poles apart.

Errata

The photographs of the two street lighting lanterns on page 372 of the November issue were unfortunately incorrectly placed in relation to the text; the upper picture is of the GEC lantern and the lower picture is of the AEI Lantern. Our apologies to readers and the firms concerned.

The picture of a luminous ceiling which appeared on page 314 of the September issue was of an earlier design on which that described in the accompanying text was based. We would apologise for any misunderstanding that may have been caused by the use of this particular illustration.

FORTHCOMING EVENTS

LONDON

December 9th

Discussion of Technical Committee Interim Report on Lighting Design Data. (At the Federation of British Industries, 21, Tothill Street, S.W.1.) 6 p.m.

CENTRES

December 1st

LEEDS.—" Photo-electric Cells and their Applications," by G. A. Benson. (At the Yorkshire Electricity Board, Ferensway, Hull.) 6.30 p.m.

December 2nd

STOKE-ON-TRENT.—Brains Trust. (At the North Stafford Hotel, Stoke-on-Trent.) 6 p.m.

December 3rd

EDINBURGH.—" Glassware for Lighting Fittings," by D. Shellshear and C. D. Cartwright. (At Y.M.C.A., 14, South St. Andrew Street, Edinburgh.) 6.30 p.m.

SWANSEA.—" Industrial Lighting Problems," by W. Imrie-Smith. (Demonstration Theatre, South Wales Electricity Board, Swansea.) 6.30 p.m.

December 4th

CARDIFF.—" Industrial Lighting Problems," by W. Imrie-Smith. (At the Demonstration Theatre, South Wales Electricity Board, Cardiff.) 6 p.m.

GLASGOW.—" Glassware for Lighting Fittings," by D. Shellshear and C. D. Cartwright. (At the British Lighting Council, 29, St. Vincent Place, Glasgow, C.1.) 6.30 p.m.

MANCHESTER.—"Recent Developments in Lighting Design Techniques," by H. E. Bellchambers. (At the North Western Electricity Board, Town Hall Extension, Manchester 2.) 6 p.m.

NOTTINGHAM.—"Lighting—and other Things—in Moscow and Leningrad," by A. G. Penny and J. F. Stanley. (At the Electricity Service Centre, Nottingham.) 6 p.m.

December 8th

LEEDS.—" Lighting Calculations for Linear Fittings from Polar Curves," by R. R. Holmes. (At the British Lighting Council, 24, Aire Street, Leeds 1.) 6.15 p.m.

SHEFFIELD.—" Display Lighting," by J. Stewart. (At the Grand Hotel, Sheffield.) 6.30 p.m.

December 9th

LIVERPOOL.—" Turning Day into Night," by G. H. Wood. (At the Merseyside and N. Wales Electricity Board Industrial Development Centre.) 6 p.m.

Situations

Wanted

JUNIOR LIGHTING ENGINEER AND ELECTRICIAN, 24, City and Guilds Intermediate, seeks employment in Edinburgh or Glasgow. Box 593.

Vacant

LIGHTING ENGINEER required for the preparation of lighting schemes. Excellent prospects and good conditions ; canteen facilities available. Please reply with full details as to experience, age and salary expected to : Herman Smith Smithlite Ltd., Empire Works, Dudley.

Harris and Sheldon (Electrical) Ltd., require LIGHTING ENGINEERS to cover Scotland, The West Midlands, Bristol and South Wales and London areas. These positions demand men able to conceive and present lighting schemes and capable of dealing at senior executive level with particular regard to multiple and departmental stores. A substantial starting salary, together with expenses, pension scheme and a car is offered. Comprehensive details of experience, etc., in confidnce to: Sales Manager, Harris and Sheldon (Electrical) Ltd., 46, Great Marlborough Street, London, W.1.

Correspondence

Levels of Illumination

Dear Sir, I am surprised to find that your contributor " Lumeritas " writes in such unimaginative terms in the November issue about the levels of illumination being provided in the United States. That a high degree of visual discomfort would result from a lighting intensity of 1,000 lm/ft^2 is certain if bare lamps in enamelled iron reflectors provide the light source, but I have no doubt that an intensity of this order in the United States is obtained through one of the very successful overall diffusing ceilings. This system of lighting allows very high levels to be achieved without glare. That your contributor is satisfied with 30 lm/ft^2 for reading in bed is understandable, and should he require some informative material to occupy his thoughts I would commend to his attention the new American IES Lighting Handbook.

No doubt your contributor is aware that the daylight intensity on even a dull day may well be in the 1,000 lumens region. I trust that this does not necessitate your contributor wearing dark glasses when endeavouring to write his Postscript.

Essex. H. COLLINS.

POSTSCRIPT By 'Lumeritas'

CHRISTMAS will soon be with us again and, for many of us, this means—among other things—putting the festive lights into commission once more. Why, I wonder, do so many of us wait for such infrequent occasions as this before making our homes gay with lights of which we ask no more than that they shall delight our eyes with their decorative effects? Of course—you say—to use the Christmas " fairy " lights all the year round would be to make them no longer distinctive—no longer a mark of a particular festival. Well, I don't suggest that the Christmas lights should be used throughout the year, but I do think that supplementary decorative lighting of some sort is well worth doing regularly in our homes. It can be done in a small or in a big way, according to our inclinations and means, and there is an almost unlimited number of interesting and attractive effects that can be produced. There are some signs of a growing interest in domestic decorative lighting, although the potentialities are very far from being generally realised.

RECENTLY, I had an opportunity of seeing the lighting in a large general hospital in one of the Home Counties. Here, I thought, I had run to earth all the conical opal glass "shades" displaced from other interiors which are now lighted more in accordance with modern standards of practice. I was wrong in this, for all these shades had been purchased new, and not so very long ago. Naïvely, I had supposed they were obsolete, but, in fact, they are contemporary plastic versions of our old familiar " friends " of many years ago. Above each bed in the wards is suspended a 60-watt pearl lamp equipped with one of these shades which does not, in fact, shade any part of the lamps—except their necks—from the view of patients who face them from opposite sides of the wards. The illumination for reading seems ample and, oddly enough, no one complains of glare. Again oddly enough, although there was the expected impairment of ability to see the details of objects in the immediate vicinity of each of these glare sources, as well as the expected after-images, I could not convince myself that I experienced any feeling which I would name as discomfort. Perhaps the reason for this is that, if one assumes the role of patient, there is no particular desire or need to make out all the details of what lies opposite in the ward and, therefore, no strong incentive to " strain " the sight to see it. The general lighting of the wards in this hospital is by centrally mounted diffusing spheres. These are considerably less bright than the visible pearl lamps over the beds, and yet they did not impress me as being much less glaring. I do not think I am unduly insensitive to glare and I would never think of recommending such an installation as I have described, either for a hospital or for any other interior in constant occupancy. Yet this experience makes me wonder whether our deprecation of such "raw" lighting does not depend, more than we realise, on its aesthetic inferiority rather than on its power to make us physically uncomfortable when we are adapted to it.

WHAT reads like a tall story was reported in the national Press last month. It concerned a so-called luminous man. The report had it that a long-distance runner was attacked by an owl one night while running through the centre of Bournemouth wearing a luminous track suit. The object of the suit was to make the runner visible to motorists and I assume that the fabric was both luminescent and fluorescent. Anyway, it appears to have made the runner visible to the owl, who ripped the front of the suit before returning to its hide-out in the trees. It happens that an owl has its habitat in the tree-lined lane in which I live, and its hooting can often be heard at night. But I have never known it to attack anyone carrying a torch, or a cyclist, at night, and I wonder whether it was the particular quality of the radiation emitted from the runner's suit which provoked the attack or whether, in fact, the suit and the attack were not really related as cause and effect. The runner is now inclined to chance being unseen by motorists rather than risk exciting attack by other owls. However, pedestrians on unlighted or badly lighted roads have been exhorted to wear some light-coloured outer garment or easily brightened object, such as an arm-band, and it may well be that fluorescent fabrics may sometimes be used for this purpose. I doubt if any pedestrian need be deterred from trying to make himself more conspicuous to oncoming motorists at night by wearing such material for fear of attack by owls. If anyone who has taken to wearing fluorescent socks or ties has had any untoward experience of this kind to report I shall be interested to hear of it.

TURNING from night to day: as I write, the sun—climbing in a cloudless sky—is burnishing the golden and coppery leaves still lingering on the trees and is throwing into clear relief the artless tracery of the myriad branches that have already lost their foliage. There is nothing drab or dreary about most natural prospects in the dying year so long as " the sun whose rays are all ablaze with ever living glory " is unveiled. The right *kind* of lighting can give some beauty to the unloveliest of things and enhance the beauty of the loveliest. Even that queer, verbally and visually repellent atrocity " a hot tin roof ", that we have heard about in the title of a recently imported play, would gain some temporary beauty if seen with the irregularly patterned shadows of a leafless tree cast athwart it. But the tree could lend none of its beauty to the roof if the light were not suitably directional.

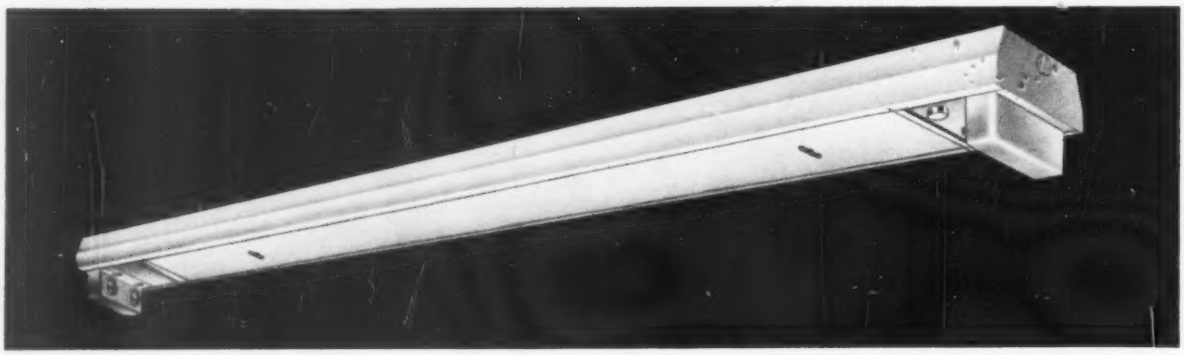
You must see the

* Revolutionary

EKCO Essex Range

PATENT APPLIED FOR

Over 200 Fluorescent Fittings from One Basic Spine



Fittings designed with the User in mind. An entirely new range of fluorescent lighting fittings, produced by experts with many years experience, to combat the ever-rising costs of installation and maintenance.

The **Essex Range** prices are very competitive with those of any fittings of the same standard, but only the **Essex Range** has all the precision built-in refinements such as:—

Detachable control gear tray, quick-fix reflectors and diffusers, heavy duty bi-pin lampholders permitting lamping from one position, no projecting screwheads on spine and many others.

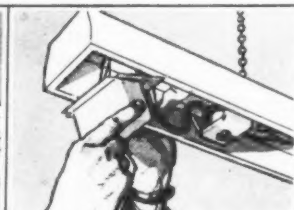
Ask for a copy of the **Ekco Essex Range** Catalogue and see how good fluorescent lighting fittings can be.

* ***Installation and maintenance cost halved.***
* ***Assembly by one man in two minutes.***
* ***Full range of quick-fix metal and plastic reflectors with open or closed ends.***
* ***Modern diffusers with coloured endplates—quickly detachable for ease of maintenance.***

INSTALLATION IS A ONE MAN JOB!

1 *Empty spine easily fixed to conduit, chain, universal suspension or ceiling. The 5ft. spine weighs only 7 lbs.*

2 *Control gear tray hooked at one end into spine, hangs vertically leaving both hands free to make connections. Tray swung into final position and firmly fixed with captive wing nut.*



3 *Ready wired lampholder assemblies slotted into spine. The gear tray and lampholders for the single 80W fitting weigh only 9 lbs.*

4 *Reflector or coverplate attached to fitting by two turn-buttons. Tube(s) inserted into spring-loaded lampholders.*

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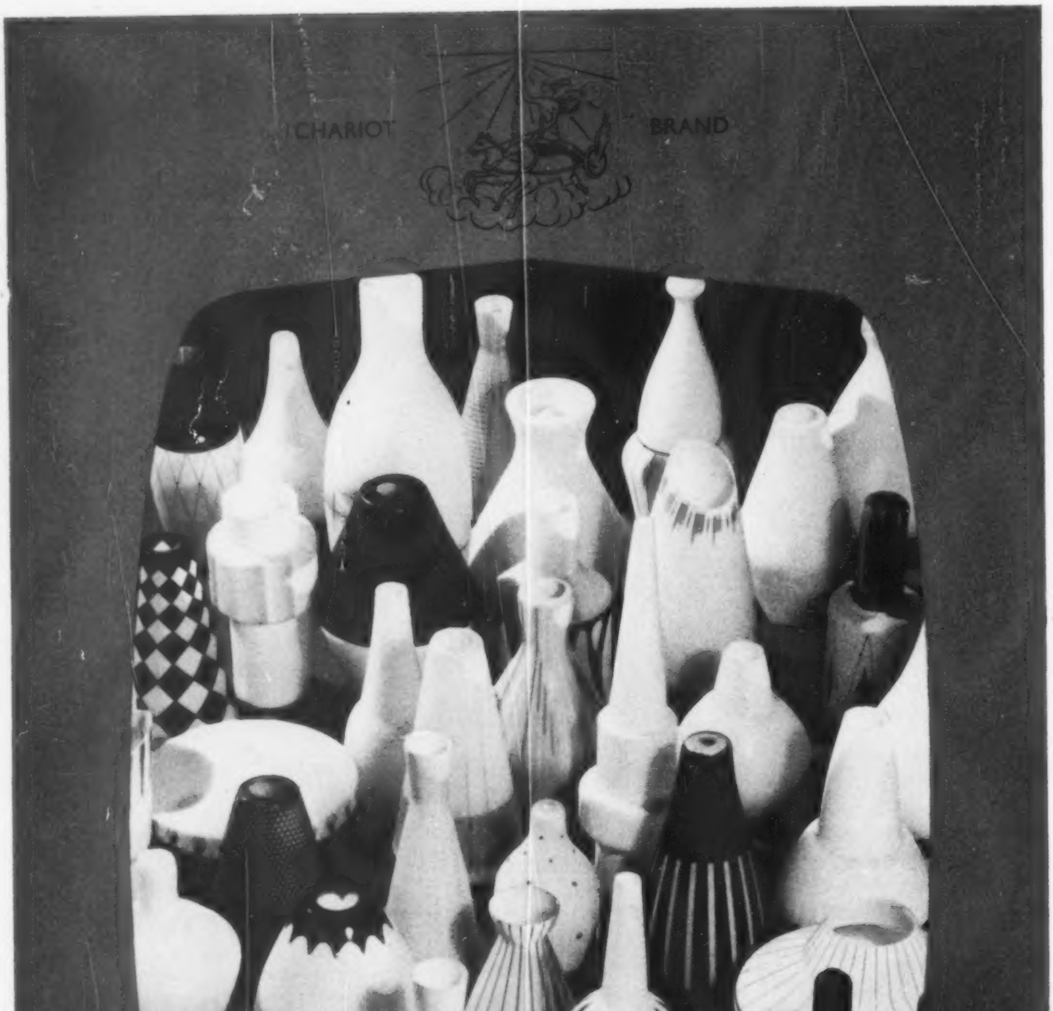

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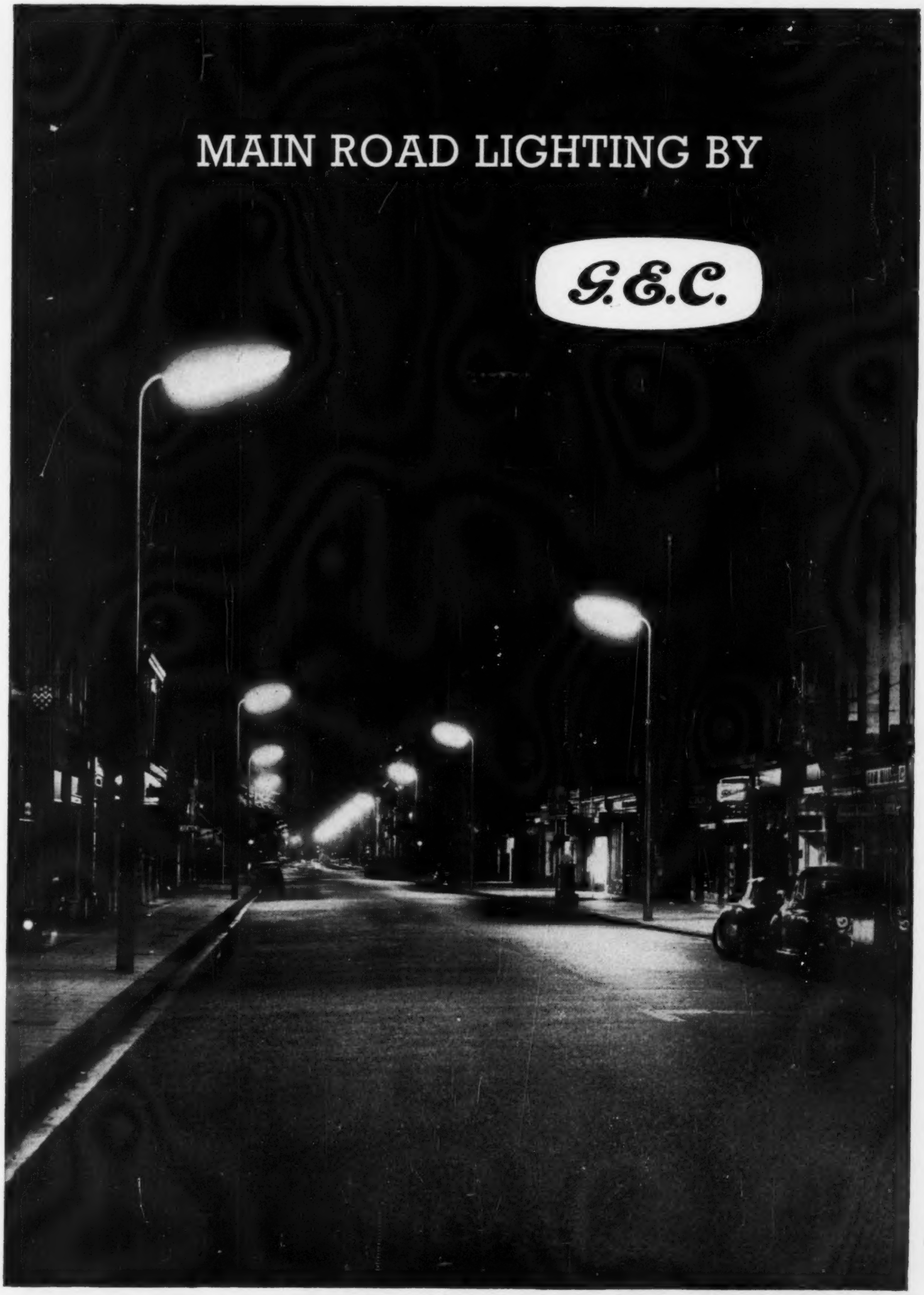
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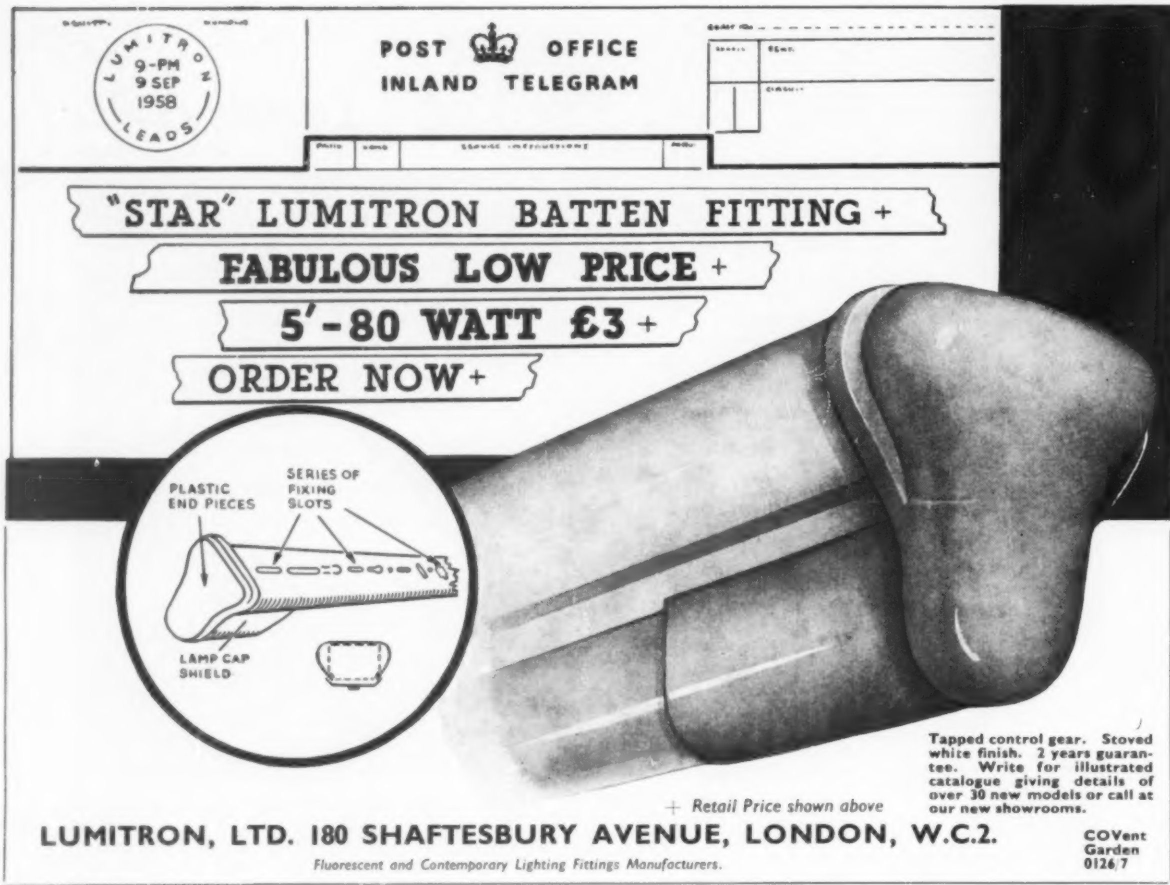

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Stanton Type 8F Prestressed Spun Concrete Lighting Columns at Stockton-on-Tees.
Photograph by courtesy of Gilbert Cowan, Esq., A.M.I.C.E., A.M.I.Mun.E., A.R.I.C.S.,
Borough Engineer and Surveyor.